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THESIS

THE CONSTRUCTION OF A LOCAL AREA NETWORK AMONG ROKM
HEADQUARTERS

(DOD, Army, Navy and Air Force)

by

Tae Gong Lee

and

Jee Ho Jeong

March 1986

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The Construction of a Local Area Network among ROKM Headquarters
(DOD, Army, Navy and Air Force)

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MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
March 1986

ABSTRACT

This thesis discusses the design issues and fundamental techniques of a Local Area Network (LAN), designs and chooses a LAN for the military. The three HQs and DoD of Korea operate their own computer center with no connection among them. All the exchange of data is performed manually and slowly. But, they want to rapidly and accurately exchange information among the fields of logistics, intelligence and operations.

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Additionally, the thesis examines the issues for designing a LAN and goes on to select four fundamental technical ingredients. These are (1) access control method, (2) transmission media, (3) topology and (4) transmission techniques. Finally, the thesis selects and recommends a military LAN; a single-cable, midsplit broadband system.

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I. INTRODUCTION

The need for communication and information exchange between computers and offices has grown rapidly in recent years. Computer technology has advanced rapidly within the past decade, resulting in the trend away from a single "batch processing" computer environment and toward highly interactive, real time, user friendly computer system. A significant problem today for all large organizations is obtaining shared access to information. Recently, each Headquarters and Defense Departments operate its own computer center separately. However, there is no communication exists among them since no connection between them. Therefore, ROKM needs some kind of communication network to improve the data communication ability among them.

This research is a portion of a project which ultimately is to provide the construction recommendations for a communications network among ROKA Headquarters and Defense Departments. The construction recommendations for the communications network aspects are the primary research areas for this thesis.

A. PURPOSE

The purpose of this thesis is multifold. The first purpose is to research the user's function through the system analysis. Second, this study highlights the user's requirements for the ROKM concept to evolve from its present state. The third purpose is to explore the critical design issues of LAN. The fourth purpose is to describe the selection process to determine the optional fundamental technical ingredients of LANs for specific operating environments. The last purpose is to evaluate the above results for the selection of a vendor and construct a model LAN for the ROKM.

B. SCOPE

The scope of this thesis is to identify and explore the specific design issues associated with a local area network. It will also discuss the system analysis and requirements for the construction of communication network for ROKM. The net result is to select the proper fundamental technical ingredients associated with specific environments. By carefully integrating user requirements with LAN implementation issues selected by decision tree, the end result should facilitate the verification of a particular LAN for the ROKM.

C. ORGANIZATION

This report contains five main chapters followed by a Conclusion and Recommendation chapter. The first chapter provides a brief introduction by defining the research objective and its associated scope of effort, and outlines the organization of this thesis. Chapter II presents the system overview and objectives which includes the need for data communication. System analysis will be discussed in Chapter III. The discussion includes the requirement analysis and model of the system which are involved in the current military system. Chapter IV presents the considerations of LAN implementation which include topology, control and channel access, transmission medium, transmission techniques, establishing transmission channels, LAN protocols and network interface units. Chapter V is devoted to the selection process in which the designer could choose one of the options from a selection tree to construct a LAN. The discussion deals with the selection process for the access control method, transmission medium, topology and transmission techniques. The next section of Chapter V discusses the LAN selected by past discussion and chooses the appropriate vender for ROKM's LAN. The last section of the this chapter

shows the required LAN associated with requirements and fundamental technical ingredients selected by a selection tree. The paper concludes in Chapter VI by stating the conclusions inferred by the discussion and a list of specific recommendations for ROKM's LAN.

II. SYSTEM OVERVIEW AND OBJECTIVES

A. INTRODUCTION

System overview and objectives is the first of the development steps to design a LAN for the ROK military. This chapter consists of two sections : system overview and system objectives.

System design is the process of planning a new system to replace or complement the existing one. But before this can be done, we must thoroughly understand the old system : that is, through the system overview, the following things will be examined - who make use of the system, what the system does, where the system is, and how the system is operated.

The ROK military system, examined by the system overview, has its missions and performs them in two different environments : field and office. The second section, system objectives, will explain what the objectives are and how they are achieved through the LAN.

B. SYSTEM OVERVIEW

This section presents a system overview providing a more complete understanding of what will be required. This will help explain how the system to be developed can best satisfy the networking requirements. The system overview consists of the following.

1. The User Community (Who)

The system consists of Army, Navy, Air Force Headquarters(HQs) and DOD. Each HQ consists of six general staffs so that it can perform its own missions. Each HQ operates its own computer center. Figure 2-1 shows the structure of the organization.

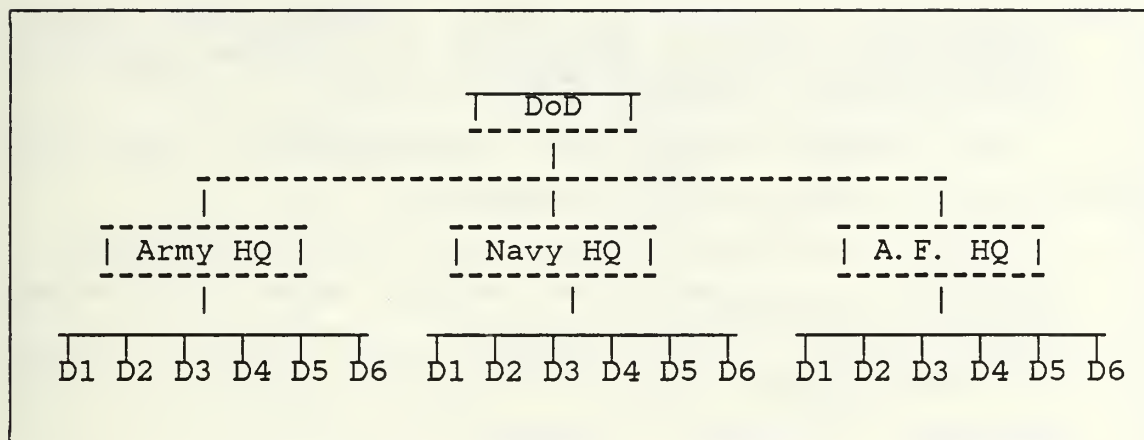


Figure 2.1 Structure of the Organization.

2. Functions (What)

General staffs organized in each HQ perform almost the same functions. The staffs develop policy and coordinate combat service support operations for deployed forces. The staffs perform the following functions :

- a) D1 (DCS Personnel) : Deputy chief of staff for personnel) : The D1 deals with all matters concerning human resources. The D1 is concerned with soldier personnel readiness and therefore, he monitors and assesses those elements of personnel administration and management which provide polices, services, and facilities affecting the soldier's human potential and commitment. D1's Primary responsibility is for the following areas: manpower analysis and personnel management.
- b) D2 (DCS Intelligence) : The D2 deals with all military intelligence matters. The D2 acquires intelligence information and data and analyzes and evaluates them. His primary responsibility is in the following areas : production of intelligence, counter intelligence and intelligence training.
- c) D3 (DCS operations) : The D3 deals with matters concerning operations, plans, organization and training.
- d) D4 (DCS Logistics) : The D4 deals with matters of supply, maintenance, transportation, and services. His primary responsibility is for supply management, facility management, equipment management and maintenance.
- e) D5 (DCS plans) : The D5 deals with the budgetary requirements of each HQs. The HQs identifies budgetary needs, and supervises the allocation and consumption of the necessary resources.
- f) D6 (DCS Civil-Military operations) : The D6 deals with all matters concerning the civilian impact on military

operations and the political, economic and social effects of military operations on civilian personnel. His primary responsibility is for civil affairs and civil/military relationships.

The staffs perform the administrative activities listed below to perform their functions.

- Letters : includes official letters and endorsements
- Reports : includes point papers, staff studies and other intra-HQ reports
- Special Orders : includes HQ special orders, bulletins and publications
- Messages : includes HQ messages
- Classified Documents : includes preparation of all classified documents
- Forms processing : includes, but not limited to, administrative action forms and fitness reports

3. Physical Location (Where)

The system to be developed consists of four major locations (i.e., DOD, Army, Navy, and Air Force HQ). All the locations are presently in Seoul. DOD is about 800 meters from Army HQ. Navy HQ is about 600 meters from Air Force HQ. Army HQ is about 8 kilometers from Air Force HQ. Figure 2-2 illustrates the physical layout.

4. Project schedule (When)

It is estimated that the system being analyzed and designed in this project will take 24 months to operationalize from the time the implementation is begun based on the system specifications recommended in this thesis.

5. Existing Plant (How)

Each HQ operates its own computer center separately. Table I shows the facilities and equipment that the locations currently have. The current configuration of the each HQ and DOD are shown in Figure 2-3.

C. SYSTEM OBJECTIVES

The major mission of R.O.K Military is to maintain the best defense capability and improve combat readiness. To

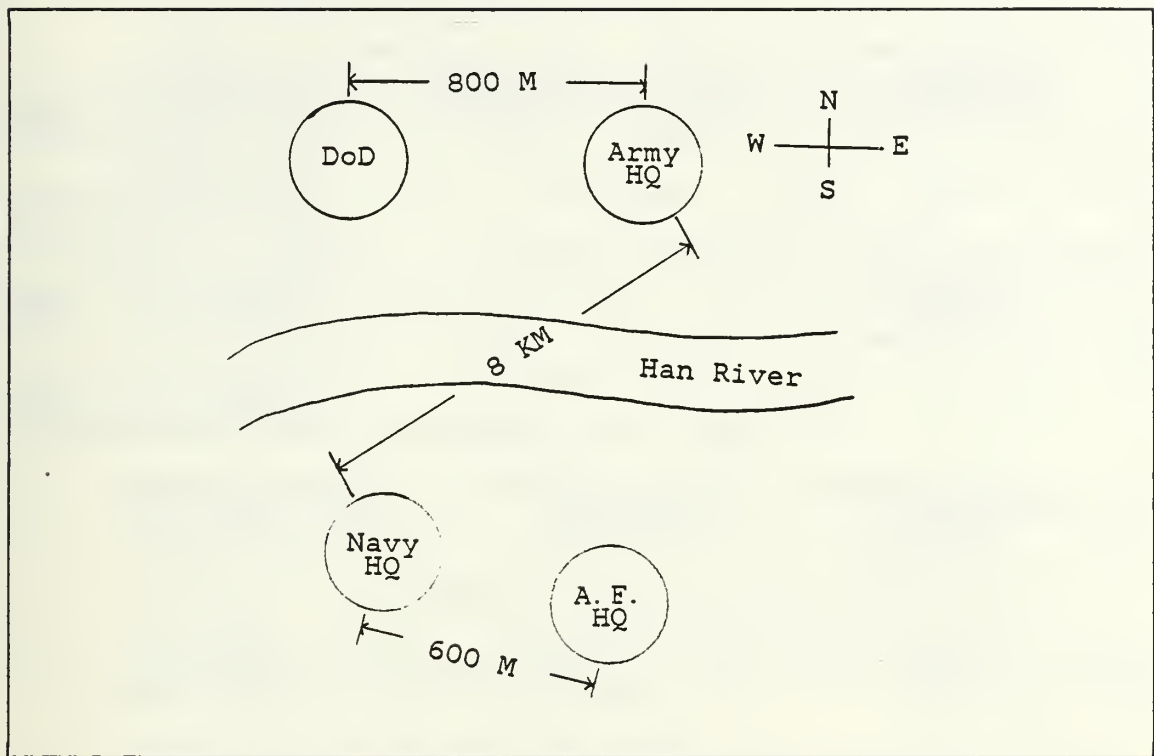


Figure 2.2 Physical Location layout.

TABLE I
EXISTING FACILITIES

Location	Computer System	Terminals
DoD	UNIVAC 1100/60	42
ARMY HQ	UNIVAC 1100/80	51
	UNIVAC 90/30	
	MDS 21/50	12
	MDS 21/50	15
	DPS 6/45	8
	PRIME 750	10
NAVY HQ	UNIVAC 90/30	4
A. F. HQ	PRIME 850	19

support this mission, military work may be divided into two categories: routine and emergency. When these two types of military work will be treated appropriately through the network, we can obtain the following objectives.

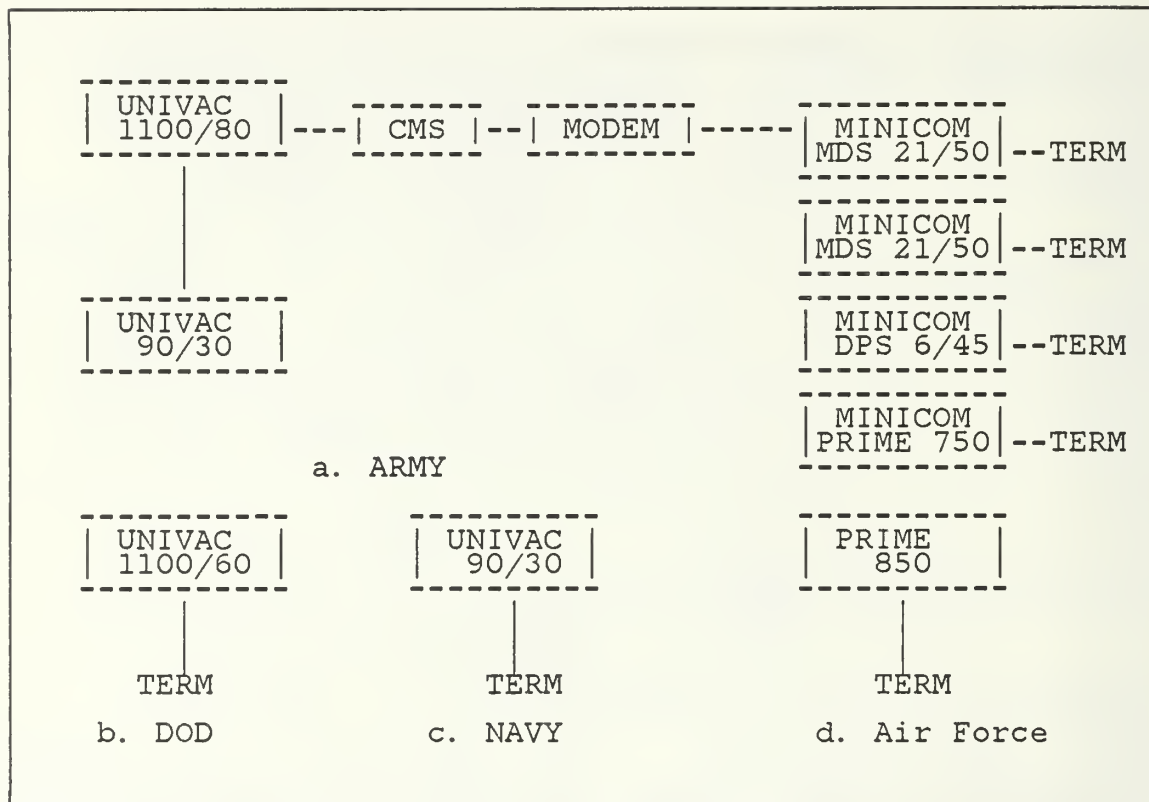


Figure 2.3 Layout of Computer Systems in the HQs and DoD.

1. Improving the Combat Readiness Capability

The R.O.K Military faces the aggressive North Korea Military just 45 KM from Seoul. The close proximity of North Korea raises the danger of sudden attack (North Korea aircraft can reach Seoul in 10 minutes). The best way to cope with this situation is to develop the ability to give ROK early warning and then to permit ROK the quickest response to the threat. Through the network, the fast exchange of current information such as enemy situation, available support resources, etc. among HQs and DOD may result in the following:

- Enables fast, accurate decisions
- Reduces the time required to mobilize forces
- Improves the system of cooperation and supply among HQs, and facilitates of cooperative combat operations

2. Providing Office Automation

Office automation is the application of computer and communications technology to improve the productivity of clerical and managerial office workers. The major functional components of an office automation system include text processing, personal assistance features and task management. The comprehensive objective of enhancing human efficiency by providing better tools for communication and decision making is supported by office integration. Fundamentals of this objective are:

- a) Repetitive tasks, formerly manually performed, will in whole or part, be transferred to machine resources whenever feasible.
- b) Attempts to optimize the most scarce resource, time, especially with regard to decision making personnel.
- c) Information which is more current should be readily available and manipulable to decision makers within all level of the organization.
- d) Increased communications efficiency through decreased expenditure of human resources.
- e) The establishment of a man/machine interface that effectively serves the needs of users.

In order to achieve these two major objectives, this thesis will design a LAN connecting the four locations and recommend only the key elements and guidelines so that the LAN can be constructed using existing technologies, hardware, and software currently available to commercial LAN markets.

III. SYSTEM ANALYSIS

A. INTRODUCTION

The purpose of this chapter is to provide requirement statements that may be used to establish a LAN for ROKM. It is also a vehicle for the ROKM to evaluate the need for a LAN.

The first section of this chapter identifies user's requirements by responsibility area within the ROKM. LAN requirements follow within which a suitable alternative may be developed to meet the user's need.

The second part of this chapter proposes a typical model of the system which represents two major functional processes involved in the current military system.

B. REQUIREMENTS ANALYSIS

1. User's Requirements

Networks combine transaction, storage and processing operations to meet user application requirements. Typically, a LAN provides these operations for specific application types. In the section, user requirements with military characteristics will be encountered and examined.

In order to obtain current and first-hand data in which the user will be required, people who were current users of the existing system or potential users of the proposed system were interviewed. In conducting interviews, the following objectives were set:

- a) Obtain quantitative data about information, distribution and management within each HQ and DOD
- b) Obtain facts about current equipment, policies, and procedures with regard to HQs and DOD
- c) Survey perceptive, and attitudes about how the current system operates
- d) Survey attitudes of HQs and DOD toward a LAN environment

Data collected in interviews is given below:

- a) Telephone communications
 - Electronic transmission of information messages
 - Ability to store and distribute messages
- b) Information production
 - Editing function (deletion, moving paragraphs, reformatting)
 - Merge capability (creation of repetitive correspondence, reports, text and files)
 - Electronic storage/retention of information produced
 - Retrieval for document creation (template, standard paragraphs)
 - Quality print capability (versatile type styles and formatting)
 - Automatic generation of charts and graphs
 - Computation capabilities
 - Creation and maintenance of file information currently on lists
- c) Information transmission
 - Electronic transmission of documents and messages
 - Automatic "standard" distribution list
 - Acknowledgement of receipt/delivery
 - Edit documents, redistribute, file, and purge
 - Electronic mail exchange
 - Facsimile
 - File access and transfer
- d) Information Management
 - Centralized filing with multiple-user accesss (within HQs and DOD)
 - Purging capability
 - File maintenance

In attempting to optimize military productivity within the military organization, it is important to note that LAN requirements must be carefully matched with unique user needs.

2. LAN Requirements

The preceding part, users' requirements handled the needs that system users need. To support the user needs (maximizing the possibility of meeting the needs of the user within ROKM), this part will describe what the LAN requires: software, transmitted information, security, reliability, interconnection of LANs and interfacing.

a. Software

Services expected of the network are the primary requirement. The protocols of the system are determined by the services the system supports.

The OSI model calls for the eventual standardization of a seven-layer communications structure, with each layer providing a consistent set of services to the adjacent layers and finally to the end user. Most vendors provide a subset of the basic network services(i.e., lower layer functions). But additional services for special application may be required. These include electronic mail, file transfer and facsimile. In order to support the above requirements, network will need software which is able to provide high layer functions.

b. Transmitted Information

Four basic types of information exist : data, voice, video and imagery [Ref. 1]. Each imposes different implementation considerations such as transmission technique and topology on the LAN. The HQs and DoD deal currently with two types of information using their own computer systems - data and imagery. They expect to transmit facsimile and graphics as well as file transfer through the network. The data type of information has the following typical attributes :

- (1) Message transfers - They are relatively short transactions, often less than 4K bytes in length. They include status and control, terminal commands and results and human message interchange.
- (2) File transfers (stream traffic, bulk transfers) - Applications include database results, archiving, interprocess file communications.

Imagery includes facsimile and raster graphics with large blocks of data generally transferred. Delay requirements are minimal compared to others and reliability requirements are not as strict as those for file transfers or terminal traffic. Imagery traffic requires protocol features within the transport and network layers. Consequently, the type of information transmitted across the LAN--data or imagery--impacts the required network services in two major ways.

The network must be capable of handling the data rates typical of the traffic type to be supported. The network must also provide the network, transport and presentation layer protocols appropriate for traffic type.

c. Security

Network security can be defined as the protection of network resources against unauthorized disclosure, modification, utilization, restriction, or destruction [Ref. 2]. Data security in computer networks is becoming increasingly important, owing to the expanding role of distributed computation, distributed databases, and telecommunication applications such as electronic mail. Additionally, the military needs to process data at various levels of security while ensuring that unauthorized access to classified information will not occur. The hierarchy of military security recognizes the need for different sensitivity levels, since not all information is equally sensitive to disclosure. The recognized sensitivity levels, in order of impact on national security, are given below;

(1) Classified

- Top secret (I)
- Secret (II)
- Confidential (III)

(2) Unclassified

In the case of a military computer network, military security is of great importance due to the existence of information that, if known by an enemy, could potentially damage the national security.

d. Reliability

Reliability is the probability that a system or component will perform its specified function under specified conditions [Ref. 2].

High system reliability is essential, such that the military may keep pace with an ever growing volume and complexity of requirements. The reliability of the system

depends on the reliability of its individual components plus the system organization. This important feature can be enhanced through use of proven technology and adequate system redundancy.

Down-time is critical for many areas of the military system. During the introduction of network capabilities into the military system, it is essential to prove to users that the new system is better and available.

Topology will be selected such that the failure of any one or combination of nodes has the least impact on network operations for all remaining nodes. An objective of system redundancy is that failure should be as 'transparent' to the user as possible. It is desirable that sufficient device redundancy be built into the topology such that acceptable system availability will be maintained. More details of this are continued in the following chapters.

e. Interconnection of LANs with other Networks

A LAN will be only part of the overall communication system used by the hosts attached to it. A very important use of the LAN is to provide an interconnection between the LAN and other networks such as long-haul networks. ROKM will require a military network to cover all of the military environment like DDN by the US DoD in the near future. The LAN proposed in this thesis will be only part of such military network. In order to resolve the problems due to interconnection of the LAN, a uniform approach to protocol design (for example, the use of the same addressing structure) must be developed. The gateway must be able to handle the problem of speed matching between the LAN and the WAN.

f. Interfacing

The LAN proposed for the HQs and DoD should attempt to integrate existing network-capable equipment to the fullest extent possible. Resources planned and now in

use in the DoD and HQs are shown in the Table I. The table says that Three nodes (DoD, Army, Navy) use the UNIVAC system and Air Force uses the Prime system. It is expected that interfacing current assets with a proposed LAN will be difficult. Maximum integration of existing equipment into the LAN will reduce buy-in costs by minimizing the diversity and volume of new equipment needed upon installation.

3. Evaluation Criteria

Desirable LAN attributes are:

- a) Adequate capabilities to meet existing Army HQ, Navy HQ, Air Force HQ, and DOD need
- b) Flexibility, such that net expansion can accommodate changing military HQs and DOD requirements
- c) Simplicity, such that military HQs and DOD can easily learn and operate the network
- d) Compatibility, to the greatest extent possible, should enable a large number and variety of equipment to exchange data on the network. Equipment of different manufactures should also be able to exchange data, allowing users the luxury of vendor independence
- e) Standards, to reach the universal level of communication, and vender-independent exchange of information across user applications and equipment functions

The following parameters are presented to define the framework in which the proposed LAN is reviewed in the next chapter.

- a) Maximum node-to-node distance - 8 KM
- b) Number of connection node - 4 (4 mainframe: Army, Navy, Air Force and DOD)
- c) Permit flexible resource sharing
- d) Facilitate high data transmission rates - exceeding 1 Mbs
- e) Facilitate low error rates - no more than one bit per 10^{**8}
- f) High system reliability - maximum down time = 4 Hours
- g) High system availability - ensure overall network availability, over a 30-day per period and 4, 44-hour work weeks, not less than 95 %
- h) Flexible growth capability - select network components that will allow for network growth in connectivity
- i) Support diverse applications - word processing, electronic mail, file transfer and resource sharing

C. MODEL OF SYSTEM

There are two major functional processes involved in the current military system. One is a military oriented process as illustrated in Figure 3-1,2 and the other is the office oriented process in Figure 3-3,4.

The data flow diagram graphically displays the processes, the units or organizations responsible for the processes, and the information that goes into and is produced by each process. Units and organizations are represented by rectangles, processes by circles, data stores by two parallel lines and data elements or structures by arrows. The supporting data dictionary and process descriptions follow.

1. Enemy Monitor System

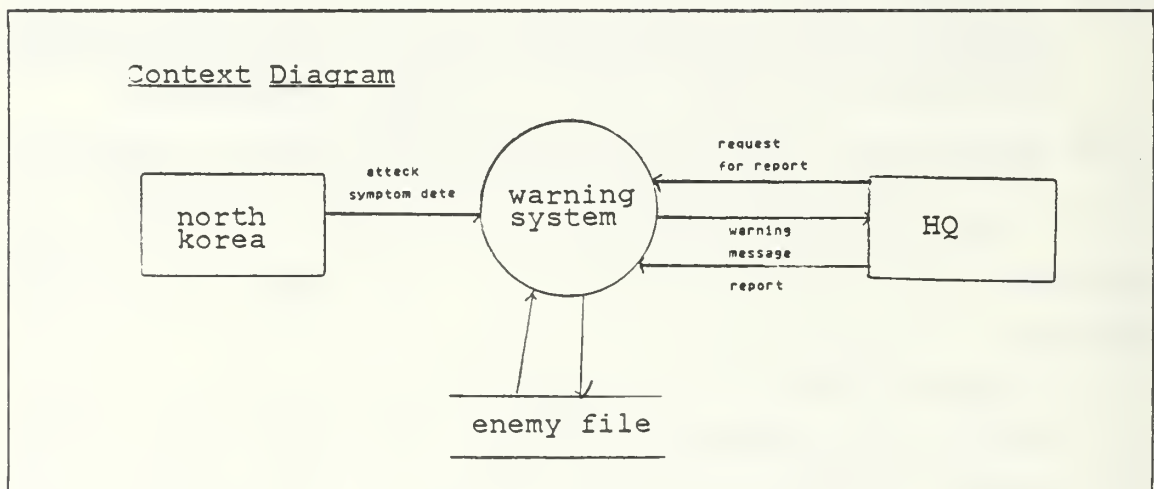


Figure 3.1 Enemy Warning System Context Diagram.

a. Data Dictionary

1. Process Name : 1.0 Local monitoring system
Description : Attack symptom data are received and integrated for further processing.
Inbound Data Flows : Attack symptom data
Outbound Data Flows: Integrated symptom data
2. Process Name : 2.0 Classify symptom data

Level 0

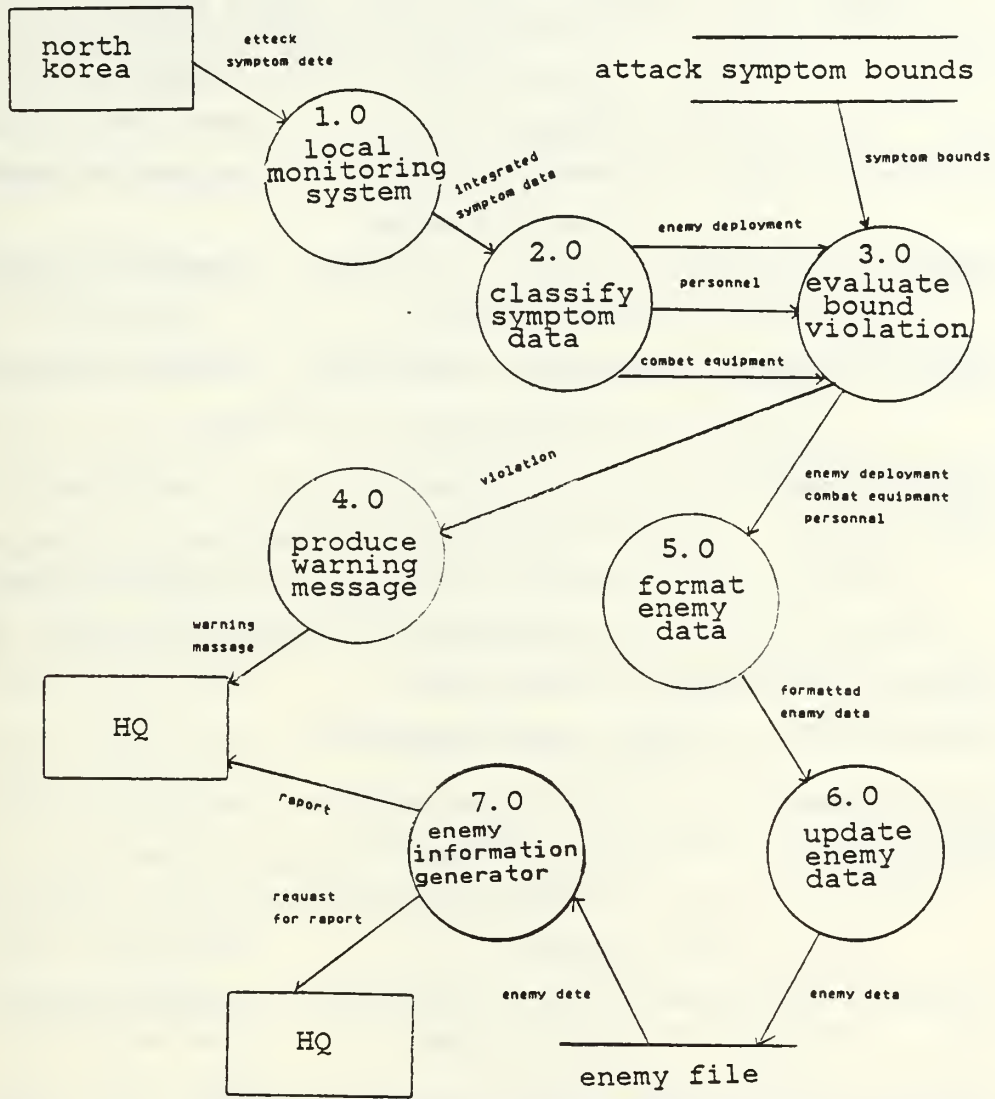


Figure 3.2 Enemy Warning System DFD.

Description : Classified as one of three major types, such as enemy deployment, combat equipments and personal

Inbound Data Flows : Integrated symptom data

Outbound Data Flows: Enemy deployment, combat equipment, personnel

3. Process Name : 3.0 Evaluate bound violation
Description : Classified data are analyzed, evaluated and compared with attack sign bounds to identify whether it is attack sign of the enemy or not. Then, if so, violation corresponding to the degree of symptom is sent to next process.
Inbound Data Flows : Enemy deployment, combat equipment and personnel
Outbound Data Flows: Enemy deployment, combat equipment and personnel, violation
4. Process Name : 4.0 Produce warning message
Description : Violation information is received and then warning message corresponding to the degree of symptom is sent to HQs.
Inbound Data Flows : Violation
Outbound Data Flows: Warning message
5. Process Name : 5.0 Format enemy data
Description : Classified data are received to produce formatted enemy data for updating enemy file.
Inbound Data Flows : Enemy deployment, combat equipment and personnel
Outbound Data Flows: Formatted enemy data
6. Process Name : 6.0 Update enemy log
Description : Formatted enemy data are received from format enemy data and are used to change the existing updated enemy file.
Inbound Data Flows : Formatted enemy data
Outbound Data Flows: Enemy data
7. Process Name : 7.0 Enemy information generator
Description : Enemy file is received from enemy

data file and is sent to generate reports for the HQs' requests.

Inbound Data Flows : Log data, Request for report

Outbound Data Flows: Report

8. Data Flow Name : Attack symptom data
Description : Enemy situations acquired from the enemy
From processes :
To Processes : 1.0 Local monitoring system
Data Structure : Enemy situation details
9. Data Flow Name : Integrated symptom data
Description : Symptom data integrated by local monitoring system
From processes : 1.0 Local monitoring system
To Processes : 2.0 Central monitoring system
Data Structure : Enemy situation details
10. Data Flow Name : Enemy deployment
Description : The situation for movement and changes in enemy deployment acquired by the intelligence collecting means.
From Processes : 2.0 Classify symptom data
To Processes : 3.0 Evaluate bound violation
Data Structure : Enemy deployment details
11. Data Flow Name : Combat equipment
Description : The situation for changes or move of major combat equipment of the enemy
From processes : 2.0 Classify symptom data
To Processes : 3.0 Evaluate bound violation
Data Structure : Combat equipment details
12. Data Flow Name : Personnel
Description : The situation of enemy military personnel derived from changes in unit

organization and troop deployment, etc.

From processes : 2.0 Classify symptom data
 To Processes : 3.0 Evaluate Bound Violation
 Data Structure : Military Personnel details

13. Data Flow Name : Violation
 Description : Bound violation results in a warning message

From processes : 3.0 Evaluate bound violation
 To Processes : 4.0 Produce warning message
 Data Structure : Violation details

14. Data Flow Name : Warning message
 Description : Message in which symptom data is analyzed, compared with symptom bounds and sent to HQs.

From processes : 4.0 Procedure warning message
 To Processes :
 Data Structure : Warning message details

15. Data Flow Name : Symptom bounds
 Description : Information that classifies the degree of attack symptom and defense condition corresponding to it.

From processes :
 To Processes : 3.0 Evaluate bound violation
 Data Structure : Enemy situation details
 Defense condition details

16. Data Flow Name : Enemy deployment, combat equipment and personnel
 Description : Data that are evaluated and prepared to format for enemy data

From processes : 3.0 Evaluate bound violation
 To Processes : 5.0 Format enemy data
 Data Structure : Enemy deployment details

Enemy combat details
Enemy personnel details

17. Data Flow Name : Formatted enemy data
Description : Symptom data prepared to updated enemy log
From processes : 5.0 Format enemy data
To Processes : 6.0 Update enemy log
Data Structure : Enemy situation details
18. Data Flow Name : Enemy data
Description : The latest data received from updated enemy log
From Processes : 6.0 Update enemy log
To processes : 7.0 Report generator
Data Structure : Enemy situation details
19. Data Flow Name : Request for report
Description : Request for report received from HQs
From Processes :
To processes : 7.0 Report generator
Data Structure : Request details
20. Data Flow Name : Report
Description : Report to explain current enemy situation
From Processes : 7.0 Report generator
To processes :
Data Structure : Report details

* Data Store *

1. Data store : Attack symptom bounds
Description : Information that represents the degree of attack symptom and defence condition.
Inbound data flows :
Outbound data flows : Symptom bounds

Data description : Attack symptom details
Defense condition details

2. Data store : Enemy file
Description : Current situation of enemy about deployment, personnel and equipment.
Inbound data flows : 6.0 Update enemy log
Outbound data flows : Enemy data
Data description : Enemy deployment details
Enemy personnel and equipment details

b. Supply Process

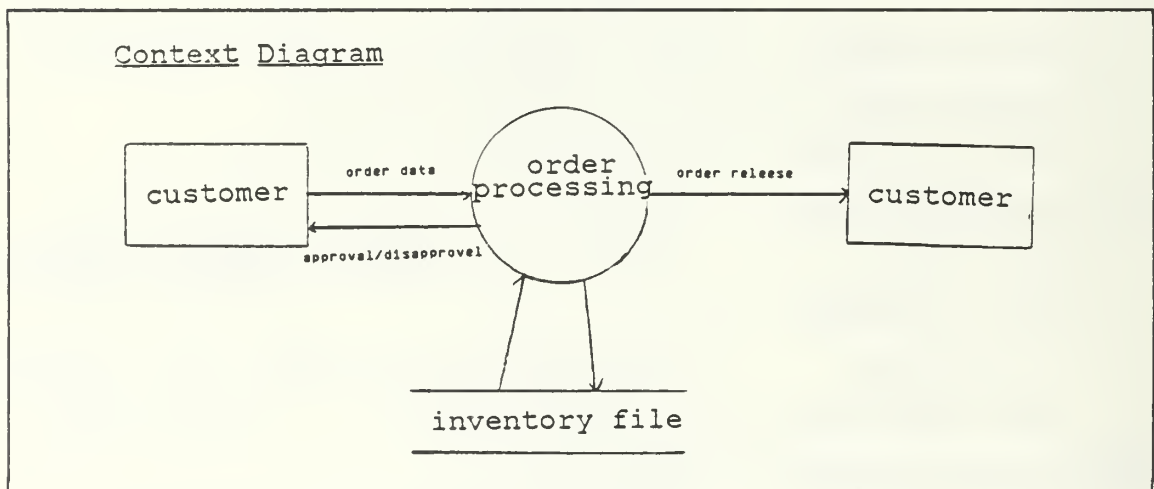


Figure 3.3 Supply Process Context Diagram.

(1) Data Dictionary.

1. Process Name : 1.0 Order approval
Description : Customer order is received and is approved or disapproved for further processing
Inbound data flows : Order data, management approval/disapproval, order limit
Outbound data flows: Approval/disapproval, verified order data, approval order
2. Process Name : 2.0 Check inventory
Description : Accepted customer order is logged to

Level 0

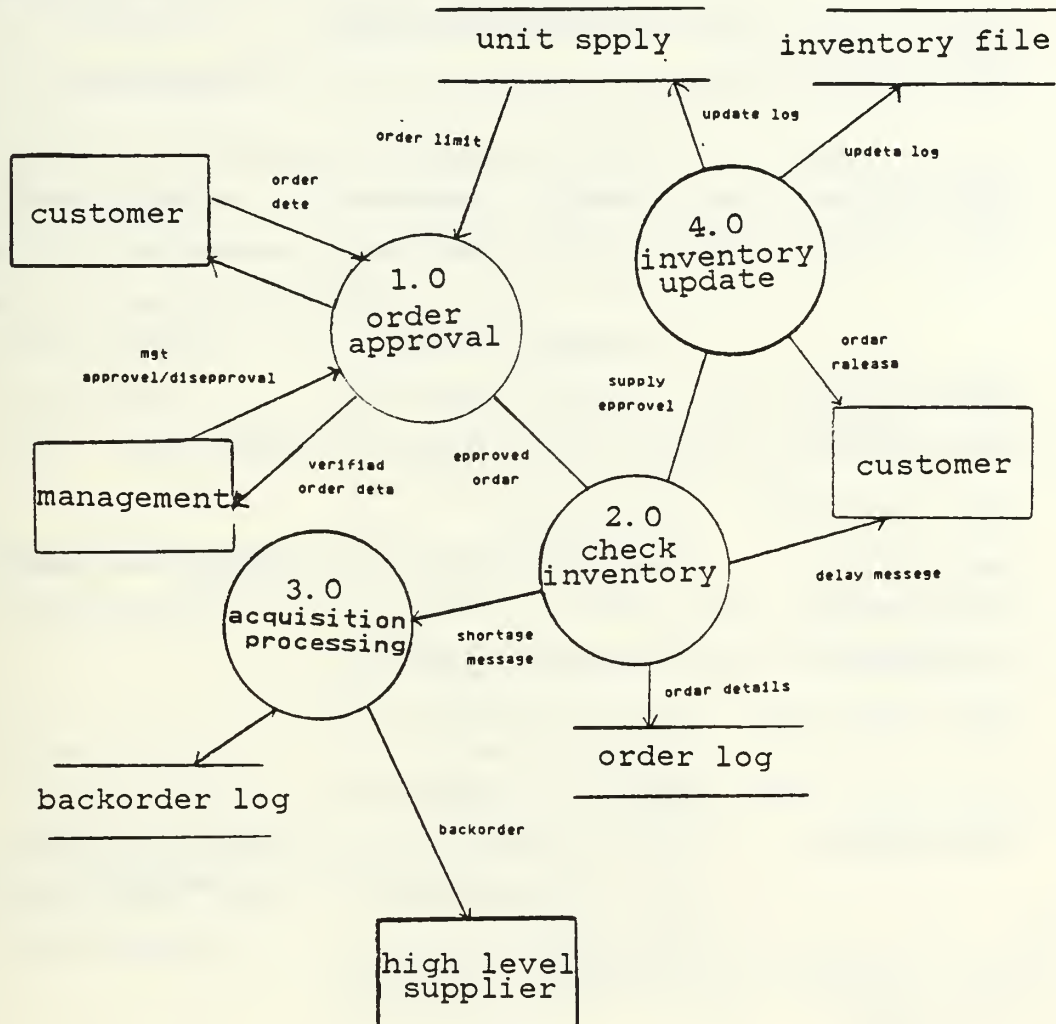


Figure 3.4 Supply Process DFD.

provide a record of all received orders. Customer order status and inventory status are checked, and if shortage exist, backorder is made

Inbound data flows : Approval order, inventory status

Outbound data flows: Storage message, order details, supply approval, delay message

3. Process Name : 3.0 Acquisition processing
Description : Where check inventory informs the
storage message, backorder is prepared
Inbound data flows : Shortage message
Outbound data flows: Backorder details, backorder
4. Process Name : 4.0 Inventory update
Description : Supply approval is received from
check inventory process and is used
to update inventory status and unit's
supply status
Inbound data flows : Supply approval
Outbound data flows: Order release, update log
5. Data Flow Name : Order data
Description : Order details received from customer
From Process :
To process : 1.0 Order approval
Data structure : Order details
6. Data Flow Name : Approval/Disapproval
Description : Acknowledgement of customer's order
reflecting approval or disapproval of
the order
From Process : 1.0 Order approval
To process :
Data structure : order details, management approval/
disapproval
7. Data Flow Name : Order limit
Description : The order limit for the part ordered by
the customer
From Process :
To process : 1.0 Order approval
Data structure : Management approval/disapproval
8. Data Flow Name : Management approval/disapproval

- Description : Management approval or disapproval of the
verified order data
- From Process :
- To process : 1.0 Order approval
- Data structure :
9. Data Flow Name : Verified order data
- Description : Customer's order after order limits
status has been checked against file
data
- From Process : 1.0 Order approval
- To process :
- Data structure : Order details, approval details, current
limit verification
10. Data Flow Name : Approved order
- Description : Customer's order after it has been
verified and received management
approval
- From Process : 1.0 Order approval
- To process : 2.0 Check inventory
- Data structure : Order details, limit verification
11. Data Flow Name : Order Details
- Description : Details from approved customer's order
which are recorded by the supply unit
in a log
- From Process : 2.0 Check inventory
- To process :
- Data structure : Shortage message
12. Data Flow Name : Shortage message
- Description : Information for shortage parts
- From Process : 2.0 Check inventory
- To process : 3.0 Acquisition processing
- Data structure : Shortage part part details
13. Data Flow Name : Backorder

- Description : Order to record the status of inventory shortage
- From Process : 3.0 Acquisition processing
- To process :
- Data structure : Backorder details
14. Data Flow Name : Inventory status
- Description : Current inventory status from inventory file
- From Process :
- To process : 2.0 Check inventory
- Data structure : Item details
15. Data Flow Name : Supply approval
- Description : Supply approval by matching the unit's order and inventory status
- From Process : 2.0 Check inventory
- To process : 4.0 Inventory update
- Data structure : Supply approval details
16. Data Flow Name : Delay message
- Description : Information to notify the customer of the delay of the ordered part due to the shortage
- From Process : 2.0 Check inventory
- To process :
- Data structure : Delay message details
17. Data Flow Name : Update log
- Description : Update data change in the inventory file and unit supply log
- From Process : 4.0 Inventory update
- To process :
- Data structure : Update log details
18. Data Flow Name : Order release
- Description : Details concerning parts ready to be released to customer

From Process : 4.0 Inventory update
To process :
Data structure : Supply approval details, order release
details

* Data Store*

1. Data store : Unit supply
Description : Data that represents the quantity
of supplies supported to unit.
Inbound data flows : 4.0 Update log
Outbound data flows : Order limit
Data description : Order limit details Unit details,
Item details Quantity details
2. Data store : Inventory file
Description : Record for all the inventory status
that supply unit contains currently.
Inbound data flows : 4.0 Update log
Outbound data flows : Inventory status
Data description : Item details, Quantity details
3. Data store : Order log
Description : Reservation of all the order data
requested by customers.
Inbound data flows : 2.0 Order details
Outbound data flows :
Data description : Unit name, Item details
quantity details, order details
4. Data store : Backorder log
Description : Reservation of all the backorder
data
Inbound data flows : 3.0 Backorder details
Outbound data flows :
Data description : Unit name, item details,
quantity details, backorder details

IV. CONSIDERATIONS OF LAN IMPLEMENTATION

A. INTRODUCTION

The purpose of this chapter is to analyze the considerations of LAN implementation by identifying the critical LAN design issues. The first section of this chapter deal with LAN objectives. The second part of this chapter presents LAN design issues. The discussion include topology, control and access, transmission medium, establishing communications channels and LAN protocols.

B. LAN OBJECTIVES

A LAN consists of two or more intelligent devices (terminals, computers and peripherals) linked in order to exchange information and share several resources. Constructing a LAN among DOD and the three HQs will accomplish several objectives and benefits such as the following:

- (1) Sharing peripheral devices to lower costs : The large capacity of the hard disk that the Army HQ has, provided by a mainframe and four minicomputers, can be shared by other HQs and DOD. Expensive but infrequently used peripherals like graphic printers can be cost-justified when used by several departments. Costly peripherals, therefore, don't need to be duplicated. A LAN makes it possible for small systems to take advantage of the greater computing power of a large system.
- (2) Sharing data files : When a HQ wants data files retained by another one, the data files don't have to be transmitted to the wanted HQ. Instead, whenever a HQ wants the data files, it can have access to the files according to security level permitted for the individuals by DOD regulations. HQs can save large amounts of hard disks because they don't have to reserve duplicated data files.
- (3) Supporting heterogeneous vendors : There are too many computer equipment manufacturers today. The very notion of LANs is their ability to interconnect such computing devices and peripheral devices within a local work environment. Enabling multivendor communication is one of the most formidable tasks of data communications. Unless manufacturers adopt common standards of communication, multivendor exchange of information could be impossible. There are not many intelligent devices and workstations required in the ROK Military LAN to be designed. But,

the LAN may require a great many intelligent devices and workplaces produced by different vendors with different capabilities. When the LAN adopts a 'standard network interface approach' - subscriber devices attach to the NIU through some standard communications or I/O interfaces, multivendor equipment can be attached to the LAN with ease.

- (4) Easy to expand : The workplace is growing and changing constantly. Adding and moving devices, and rearranging the shape of the LAN must be possible. Changes to the LAN should cause little, if any, disruption in the operation of the network. As seen earlier, the LAN is a first trial for the ROK military environment. This means that in the near future, the LAN will contain many devices and workstations as the workload on the network increases over time. At that time, the LAN should accommodate the more devices or workplaces easily.

C. LAN DESIGN ISSUES

1. Topology

The term topology, in the context of a communications network, refers to the way in which the end points or stations of network are connected. Topology is the pattern of interconnection used among the various nodes of the network and is defined by the layout of communications links and switching elements. It determines the data paths that may be used between any pair of stations. Topology influences the performance, reliability, and control strategy of local networks. One approach is an unconstrained graph structure, with node connected together in an arbitrary pattern, as illustrated in Figure 4-1 [Ref. 3].

In this approach, each device or station connects directly to a communications network node and communicates to other stations via a network. This general topology has no significant relative advantage in a local area network and imposes a degree of complexity at each node. A variety of constrained topologies have been developed with attributes particularly suited to local networks. We shall consider four such topologies; bus, tree, star and ring. These are commonly used to construct local networks.

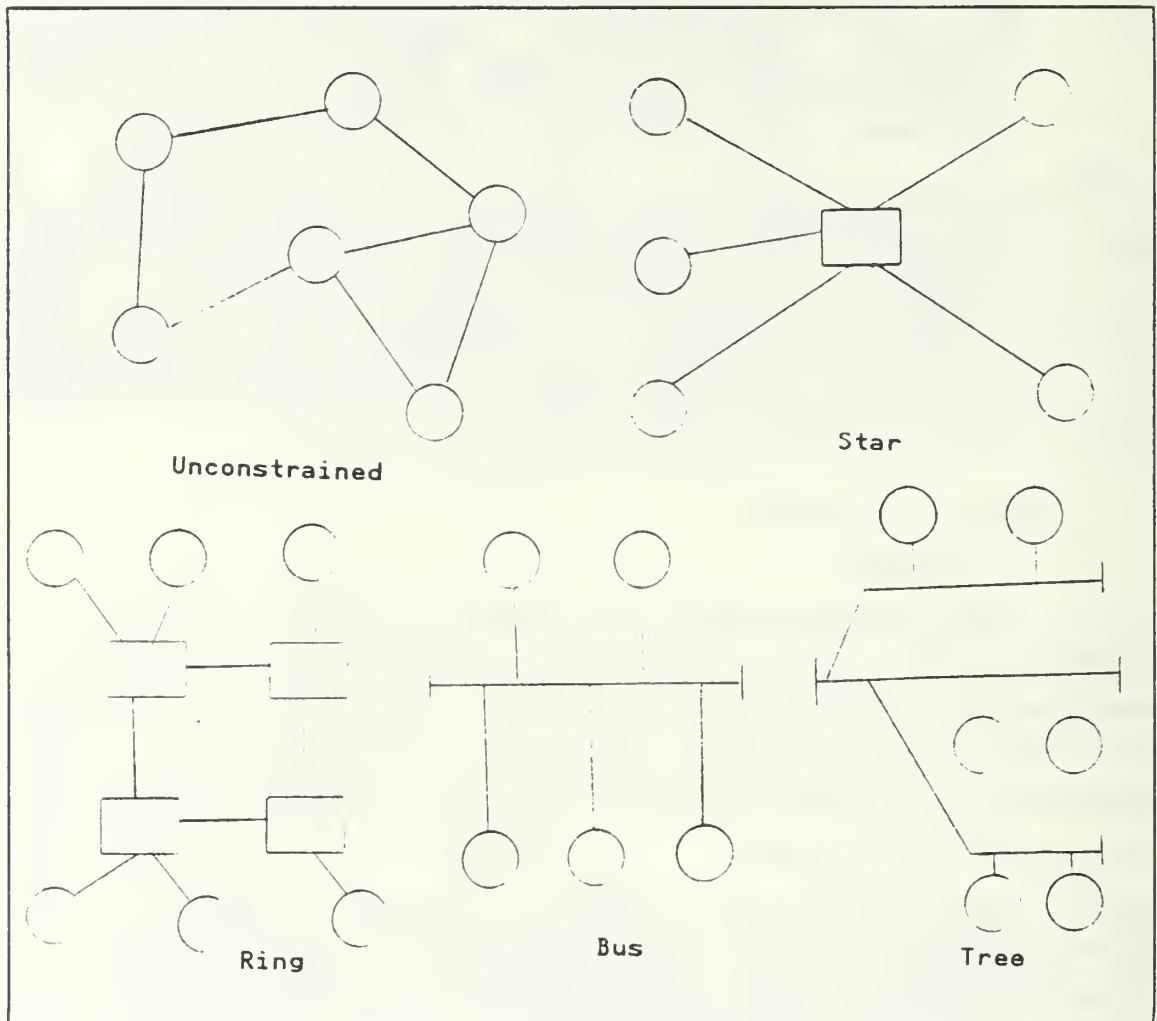


Figure 4.1 Topology.

a. The Star Topology

In the star topology, illustrated in Figure 4-1 [Ref. 2], each station is connected by a point-to-point link to a central switching station. Communication between any two stations is via the switching station. Therefore, this topology eliminates the need for each network node to make routing decisions by localizing all message routing in one central node. This leads to a particularly simple structure for each of the other network nodes.

b. The Ring Topology

In a ring [Ref. 2], illustrated in Figure 4-1 the local network consists of repeaters joined together by point-to-point links, usually in the shape of a circle. This topology attempts to eliminate the central node on the network without sacrificing the simplicity of the other nodes, though elimination of central node does imply a certain complexity at other nodes of the network. A decentralized network can be constructed with a surprisingly simple node structure. A station is attached to the network by a repeater that provides intelligence in the transmission and reception of data. The repeater is a comparatively simple device, capable of receiving data from one link and retransmitting it to another link. The data circulates around the ring in one direction.

c. The Bus Topology

In a bus topology, pictured in Figure 4-1, no routing decisions are required by any of the nodes. In this approach all attached stations share a full-duplex transmission medium with all devices receiving all transmissions. Therefore, a message flows away from the originating node in both directions to the ends of the bus. The destination node reads the message as it passes by. Again, a node must be able to recognize messages intended for it. However, unlike nodes in a ring, they do not have to repeat and forward messages intended for other nodes. There is none of the delay or overhead associated with retransmitting messages at each intervening node and nodes are relieved of network control responsibility at this level.

d. Tree Topology

The tree topology is a generalization of the bus topology. The transmission medium is a branching cable with no closed loops. A transmission from any station propagates throughout the medium and can be received by all other

stations. The tree provides the flexibility needed to carry LAN service to several floors of building or to several buildings a campus setting. Figure 4-1 shows an the example of tree topology.

2. Control and Channel Access

Control and channel access schemes must be implemented in conjunction with network topologies to provide the performance and operational characteristics desired for the intended applications of the LAN. The key parameters in any medium access control techniques are where and how. Control strategies describe where control of access and allocation resides in the network (i.e., centralized or distributed). The second parameter, however, is constrained by the topology and is a trade off among compacting factors: cost performance and complexity. There are two kinds of access techniques, polling and contention.

a. Polling

Polling techniques determine the order in which nodes can take turns accessing the network. Access is predetermined by a schedule that guarantees each node a chance to transmit at a specific point in the polling order. Polling networks offer deterministic access to the channel by each node.

b. Centralized Polling

In centralized polling, illustrated by Figure 4-2 [Ref. 4], the central computer asks each node if it has a message to send. If so, the node is directed to send it. The central computer then asks the next node, and so forth, in round-robin fashion. In this access method, if none of the nodes has a message to send, the control node is asking a lot of questions for nothing. Centralized controlled polling, as explained above, can be implemented in any topology. In all case, the central node decides which node is to access the network at any one time.

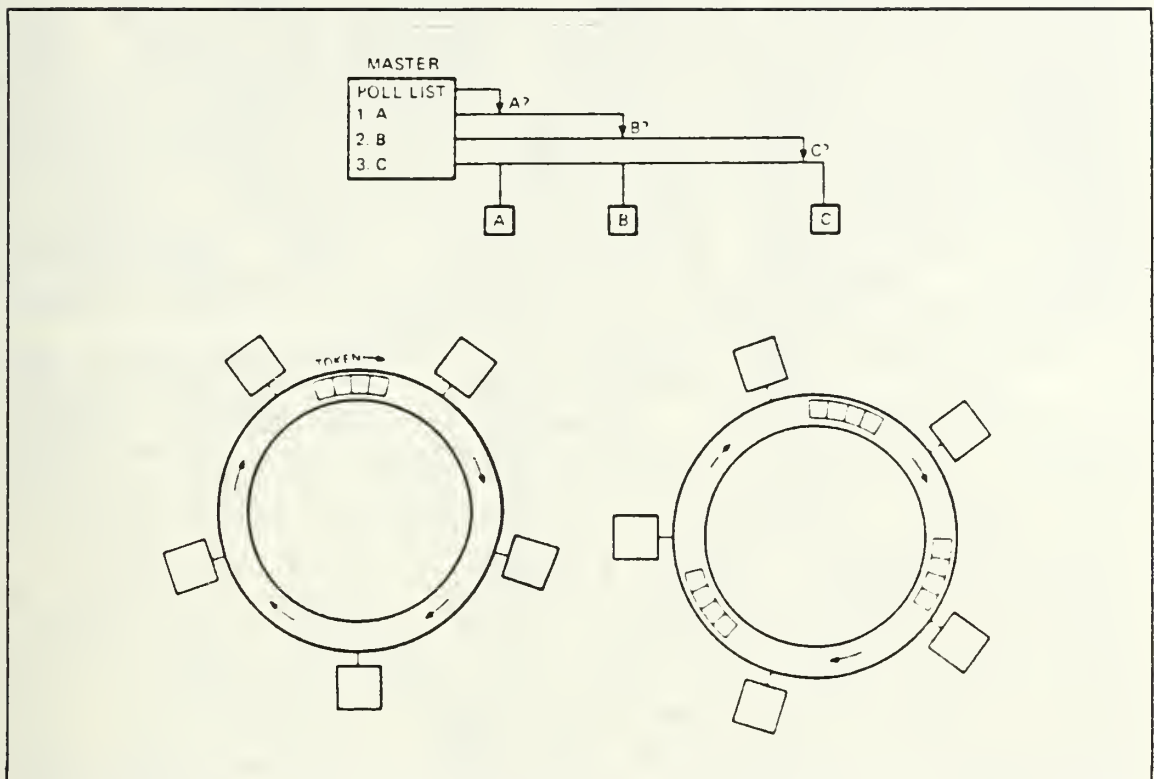


Figure 4.2 Access Method.

(1) Distributed Polling. In token polling, control is distributed by means of a polling message, called a token, which is passed from subscriber to subscriber and triggers data transmission. In this way, access conflicts are avoided and control of access is located in each node.

Both token passing and slotted rings are frequently discussed methods of distributed polling.

(a) Token Passing: This technique (Figure 4-2) is based on the use of a token (a special bit pattern) which circulates around a ring from node to node when there is no message traffic [Ref. 4]. A node wishing to transmit must wait until it detects a token and then it will "hold" the token and send its message, specifying the destination address. Each node on the ring checks the message as it passes by. It is the responsibility of nodes not only to

identify and accept messages addressed to them but also to repeat and pass on messages addressed to other nodes. Messages must circulate back to the sending node to confirm receipt by the destination node. When a node is finished sending its message, the sending node releases a new free token. The next node will then be able to seize the token and transmit. The size of the message is determined by the design of the network's allocation scheme.

(b) Slotted Ring: In the slotted Ring pictured in Figure 4-2, messages are transmitted during a slot and all point-to-point links form the ring. Slotted rings employ a variation of token passing access control in the ring network. Usually a number of slots, or frames, of fixed size circulate around the ring. A slot may be empty or full, and any node, upon noting an empty slot passing by may mark the slot as full and place a message in it (i.e., if a node chooses to transmit, it waits for a free or unused slot, insert data into the appropriate field, sets a bit to indicate that the frame is full and indicates the source and destination address). An example of this scheme is the Cambridge ring.

c. Contention Techniques

Contention techniques anticipate conflicts or collisions and actually use them as part of the design to allocate the common channel. In this approach there is no predetermined order of access by stations.

(1) CSMA/CD. Carrier Sense Multiple Access with Collision Detect (CSMA/CD) employs the contention control concept. CSMA/CD, because of the CD part, is appropriate only for a bus/tree topology. With CSMA/CD, a subscriber transmits only when the broadcast medium is sensed idle and stops transmitting if a collision occurs. Carrier sense is the ability of each station to detect any traffic on the channel (called listen-before-talking)

[Ref. 4]. Stations defer or wait whenever they sense that there is traffic on the channel. However, because of propagation delay, collisions between two messages do occur. Collision detection is the ability of the transmitting node to detect a collision. If a collision is detected during transmission, frame transmission is ceased, and a brief jamming signal is transmitted to assure that all stations know that there has been a collision. After transmitting the jamming signal and waiting for a brief interval, and transmission is attempted again. The period before retransmitting is either fixed or random. Owing to the ability to listen before and during transmission, the number of collisions can be quite low and successive collisions between nodes are rare. Thus, CSMA/CD is a highly efficient form of distributed access. This is especially true when packets are larger. CSMA/CD's main advantage lies in its simplicity, Its disadvantage is the increased probability of collisions under heavy communication environments.

3. Transmission Medium

The transmission medium provides the physical connection between equipment in a communications network. There are three important transmission media in local networks, such as twisted pair, coaxial cable and fiber optics. The choice of medium impacts the transmission capacity, reliability, ease of installation and maintenance of local area networks.

a. Twisted Pair

The most common transmission medium for both analog and digital data is twisted pair. It consists of two insulated wires arranged in a regular spiral pattern. A wire pair acts as a single communication link. Normally, these pairs are bundled with a number of other twisted pairs in a protective sheath. Twisted pair can be used to transmit both analog and digital signals. Digital data can

be transmitted over an analog voice channel using a modem. It is also possible to use digital or baseband signaling on a wire pair. Twisted pair wire is easy to install and move around. Noise immunity is achieved by proper shielding and different twist lengths for nearby pairs in a bundle. Therefore, environmental noise usually requires the use of conduit to protect the wire. Twisted pairs have severe distance limitations as signals attenuate quickly. Data rate potential is roughly below 10 megabits per second. It is commonly used for connection of low speed data equipment, such as terminal, that operate at speeds of 300 to 9.6 K bit per seconds.

b. Coaxial Cable

Coaxial Cable has been the most popular medium for local area networks. "Coax" usually consists of a central conductor wire surrounded by an insulation layer which is enveloped with a metallic sheath conductor. Coax provides very high bandwidth and has good resistance to noise. However, it is expensive to buy and difficult to install due to its stiffness. There two types of coaxial cable currently in use for local area network applications; 75-ohm cable, which is the standard used in community antenna television (CATV) systems, and 50-ohm cable which is used for analog signaling with FDM, called broadband. Baseband uses 50-ohm cable with data rates typically below 10 between 15 megabits per second. In broadband local networks, the capacity is used to create a large number of frequency subchannels from the one physical channel. Coaxial cable commonly used for CATV (and broadband local area network) has available bandwidths in the range of 300-400MHZ. This translates into sufficient capacity to carry over 50 standard six MHZ color TV channels or thousands of voice-grade and low-speed data signals (for example, 9.6, 19.2 or 56 K bits per second) [Ref. 4].

c. Fiber Optics

Optical fibers are made of plastic or glass and can serve as a very high performance transmission medium in certain applications. They are immune to noise interference, have significantly higher potential bandwidth and are secure from intruders tapping into the local network. However, the technology is still evolving about the various types of fiber optics. The characteristics of fiber optics are given below [Ref. 4] ;

- (1) Currently available fibers have usable bandwidths of up to 3.3 GHz compared with the upper limit of 500 MHz for coaxial cable.
- (2) Data rates of over one G bits per second have been supported.
- (3) Error rates are very low (one bit error per 10 bits).
- (4) Fiber optic transmissions are not affected by electrical or electromagnetic interference nor do they emit noise, making them inherently secure.
- (5) They are very small and light, saving space and weight.

4. Transmission Techniques

a. Baseband

Generally, baseband refers to the transmission of an analog or digital signal in its original unmodulated form. When transmitted they reside at the base of the channel bandwidth. In the LAN world, baseband is defined more stringently as a transmission technique using a digital signal. Hence frequency-division multiplexing can not be used. Transmission is bidirectional. Baseband LAN implementations most frequently use the bus Topology with contention control usually CSMA/CD. Figure 4-3 is an example of a baseband system with three segments and two repeaters [Ref. 2].

b. Broadband

In LANS broadband refers to the use of analog signalling, with one of many frequency division multiplexing techniques. The smaller channels created by FDM can be

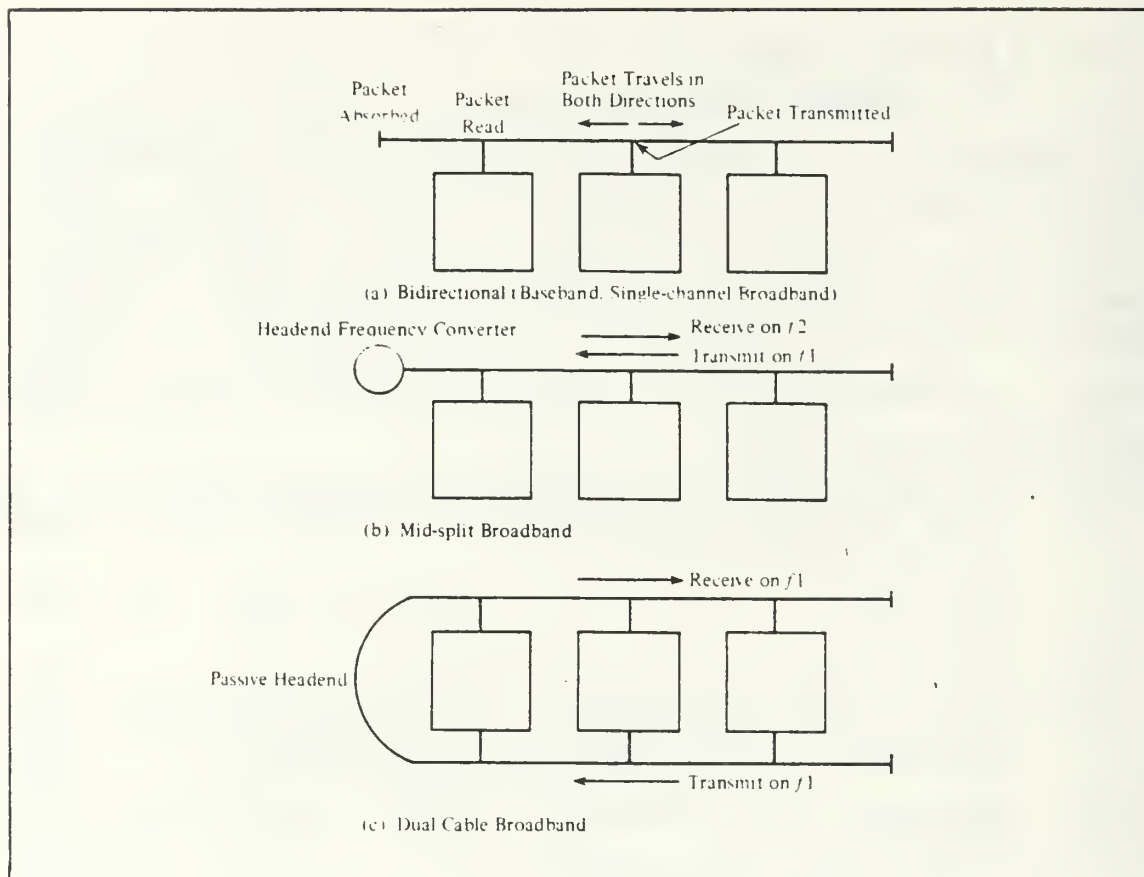


Figure 4.3 Transmission Techniques.

allocated different bandwidths so they can be used to transfer different forms of information, specifically voice, data and video. It is a unidirectional transmission technique. Much greater distances are possible with broadband as compared to baseband since the analog signal can propagate a greater distance before noise and attenuation damage the data. Figure 4-3 shows a typical broadband system [Ref. 2].

5. Establishing Communications Channels

Communication is achieved by transmitting data from a source to a destination through a network of intermediate nodes. In order for message to travel across the network, a transmission path must be established to switch or route them to their destination. The collection of devices that

wish to communicate are referred to as stations. A collection of devices whose purpose is to provide communications are referred to nodes. Each station attaches to a node. The collection of nodes is referred to as a communication network. Three switching techniques are in common use: circuit switching, message switching and packet switching [Ref. 2]. The packet switching which is commonly used to LAN environment will be examined below and the other switching techniques are shown to Appendix A.

a. Packet Switching

Packet switching represents an attempt to combine the advantages of message and circuit switching while minimizing the disadvantages of both. Packet switching is very much like message switching. The principal external difference is that the length of the units of data to be transmitted is limited in a packet-switched network. Packets can be fixed or variable length, but generally have specified maximum length (e.g., 128 bytes). Message switching systems can accommodate large messages. When a message is large than the maximum packet size, it is broken into packets and transmitted. This stream of packets via packet-switched network is handled by two methods : datagram and virtual circuit [Ref. 2].

- 1) Datagram : In the datagram approach, each packet is treated independently, just as a message-switched network. The route each packet takes can differ and the packets that make up a message can arrive at their destination out of order, depending on traffic and the assigned routing priorities of the network. Reassembly is accomplished in different ways, depending on the network or computer system, most often by higher-level software protocols.
- 2) Virtual circuit : A logical connection is established before any packets are transmitted. But this does not mean "a dedicated path", as in circuit switching. A packet is still buffered at each node, and queued for output over a line. The difference from the datagram approach is that the node need not make a routing decision for each packet. It is made only once for each connection.

If two stations must exchange data over an extended period of the time, there are certain advantages to

virtual circuit because relieving the stations are released of the unnecessary communications processing function. Advantages of the datagram are : 1) the call setup phase is avoided, 2) because it is more primitive, it is more flexible, and 3) more reliable because packets may find alternate paths if a node is lost. It is also possible for packets to be "broadcast" over a medium. In such instances, all nodes merely check each packet as it passes by to determine if it is addressed to them, and ignore it if it is not. This approach eliminates the delay inherent in routing packets from node to node. It is commonly used in local area networks.

6. Communications Standards and Network Architecture

In recent years, there has been a proliferation of intelligent equipment and computers from many manufacture's, which are widely distributed throughout organizations. When communication is required among heterogeneous equipment, the hardware is reasonably standard and generally has few problems. However, communications software development can be a nightmare. Communications between these systems and networks can only be possible if they abide by some common set of rules. In other words, distributed systems and networks require standards for communications.

a. The OSI Layers

The Open Systems Interconnection (OSI) model is a framework for defining standards for linking heterogeneous computers. The OSI model represents a widely accepted structuring technique known as "layering". A network architecture specifies a hierarchy of independent layers that contain modules for performing defined functions which are required to communicate with other system within the network. Communication is achieved by having the corresponding layers in two systems communicate. The architecture defines two kinds of relationships between functional modules [Ref. 4] ;

- 1) Interfaces - relationships between different modules operating within a network node. Typically, a module in one layer will interface with a module in the layer below it to receive a service.
- 2) Protocols - relationships between equivalent modules, usually in different nodes. Protocols, a set of rules or conventions, define message formats and rules for message exchange.

The OSI model (Appendix B), by defining a 7-layer architecture, provides a framework for defining these standards. Figure 4-4 illustrates a 7-layer architecture of the OSI model [Ref. 5].

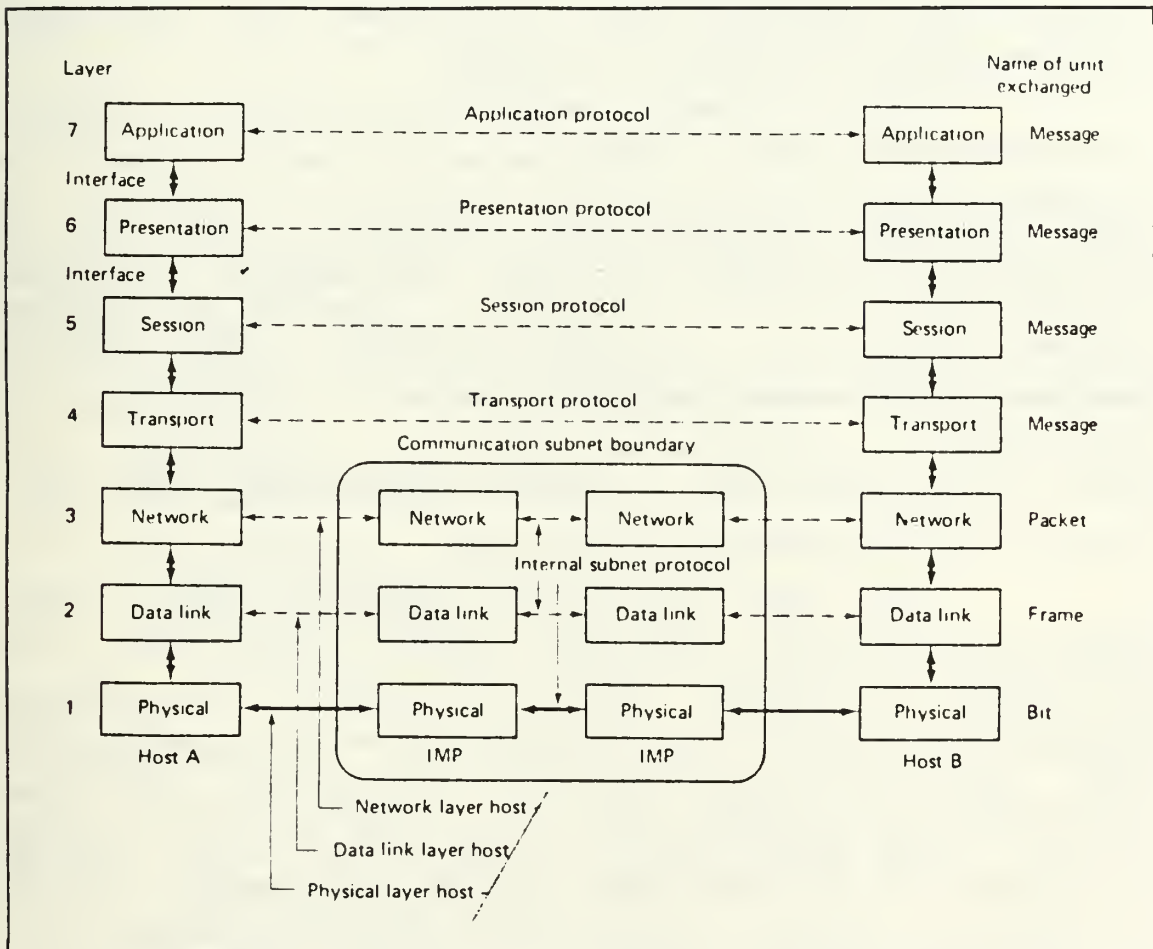


Figure 4.4 The OSI Model.

b. Characteristics of Layered Network Architecture

Layers are independent of each other and defined by function. Hence, they can be changed and enhanced without substantially affecting other layers. This is important for adapting continually changing communications technology and developing communications standards. Standards that specify new or superior means of data transmission and information exchange can be integrated into the network as they develop. Currently, emerging standards for local area network communications are beginning to be integrated into the network architectures of a number of vendors.

By conveniently supporting upgrades, updates, and new communications technologies and capabilities, the layered network design approach can protect customers and their application investments networking systems. A layered design is also important in terms of computer hardware and firmware technology. Functions performed in the software modules of the network architecture will, over time, be transferable to hardware and firmware - particularly as a result of standardization of more communications functions.

c. LAN Protocols

LANs have two important characteristics. First, data is transmitted in addressed frames. Second, there is no intermediate switching, hence no routing is required (repeaters are used in rings and may be used in baseband bus LANs, but do not involve switching or routing). We can see from these two characteristics that the minimum essential communications functions that must be performed by the LAN correspond to layers 1 and 2 of the OSI model(Appendix B).

Throughout, reference is made to the IEEE 802 standard, providing a framework for exposing and clarifying LAN communication architectural issues. Figure 4-4 illustrates the relationship between the OSI model and LAN protocol layers of the IEEE 802.

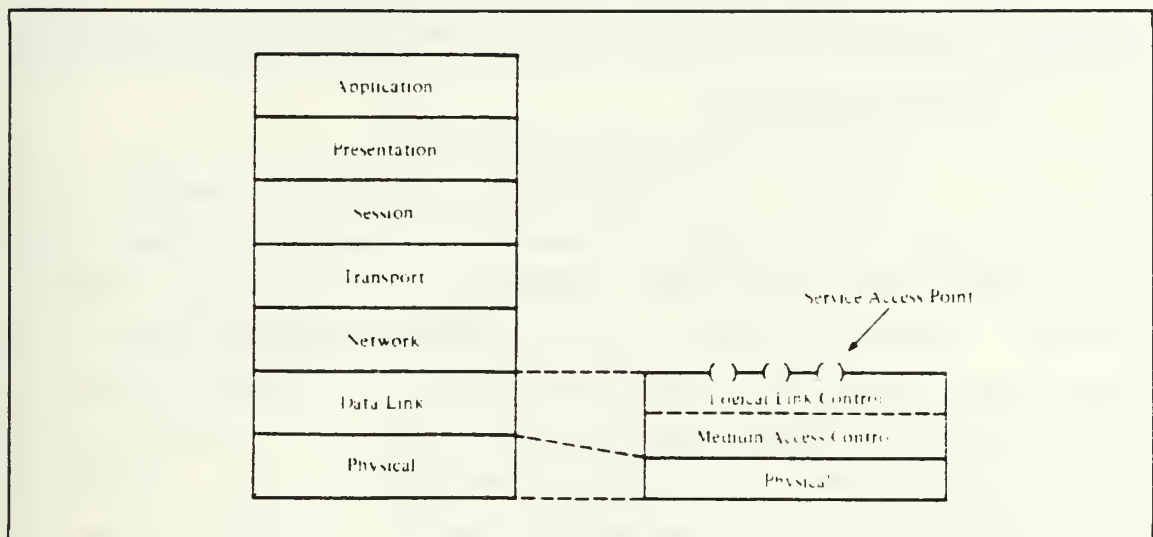


Figure 4.5 LAN Protocol Layers Compared to OSI.

At the highest levels are the functions associated with accepting transmissions from and delivering receptions to attached stations include [Ref. 2] ;

- (1) Provide one or more access points. A service access point is a logical interface between two adjacent layers.
- (2) On transmission, assemble data into a frame with addresses and CRC fields.
- (3) On reception, disassemble frame, perform address recognition and CRC validation.
- (4) Manage communication over the link.

These are the functions typically associated with layer 2, the data link layer. The first three, and related functions, are grouped into a logical link control (LLC) layer by IEEE 802. The last function is treated as a separate layer, called medium access control (MAC). This is done for the following reasons [Ref. 2] ;

- (1) The logic required to manage access to multiple-source, multiple-destination link is not found in traditional layer 2 link control.
- (2) For the same LLC, several options may be provided.

Finally, at the lowest layer, are the functions generally associated with the physical layer, as with the

OSI model. These include encoding/decoding of signals, preamble generation/removal, and bit transmission/reception.

7. LAN Components

a. Network Interface Unit (NIU)

The NIU is a set of intelligent devices that implement the local network protocols and provide an interface capability for device attachment. The NIUs, collectively, control access to and communications across the local area network. Subscriber devices attach to the NIU through some standard communications or I/O interface. The NIU transforms the data rate and protocol of the station to that of the network transmission medium and vice versa. In general terms, when transmitting data, the NIU accepts data from attached devices. Buffers the data until transmitted, transmits on the medium, receives the data addressed to its own device and vice versa. Figure 4-6 illustrates a generic architecture for a NIU. [Ref. 2]. This NIU can be usually explained by the two parts of CIU (Communication Interface Unit) and BIU (Bus Interface Unit). Appendix C explains the functions of CIU and BIU in more detail.

b. Network Nodes

Nodes are the basic information-processing units that are directly connected to a network - single addressable entities. In addition, there are typically two types of nodes that will play a greater role in LANs. These nodes, which provide specific services to networks, are bridges and gateways. As network traffic increases, a significant portion of node activity can be taken up with routing messages between networks. Bridges and gateways are dedicated systems whose purpose it is to offload this function from the other network nodes so that they can do more general purpose, user-oriented processing.

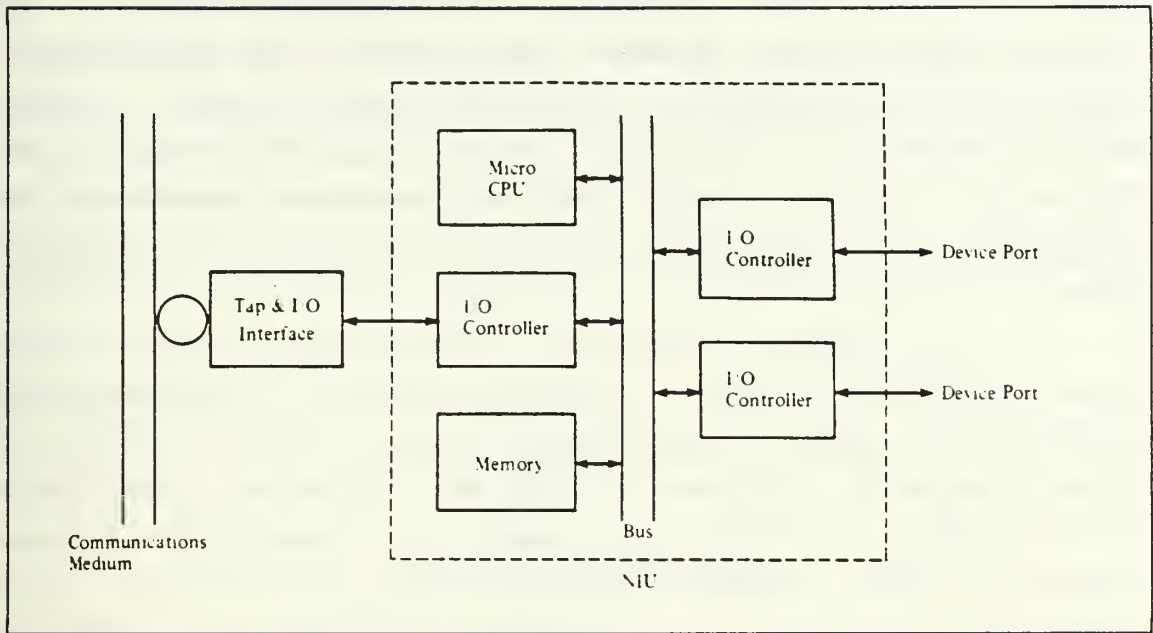


Figure 4.6 NIU Architecture.

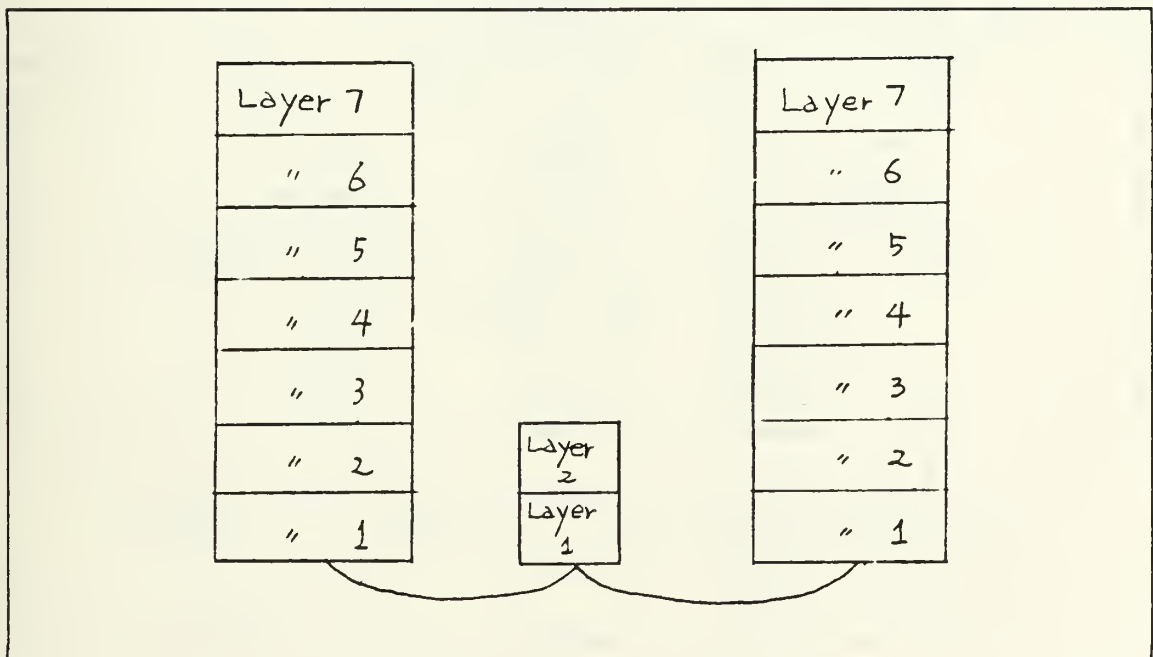


Figure 4.7 Connection of LANs through Bridges.

A bridge offers more functionality than a repeater. See Figure 4-7. This device acts the frames of

data sent over a LAN, storing and forwarding frames to the proper destination. Bridges are needed when extending a frame from a LAN through a different physical link. In terms of the OSI model, levels 1 and 2 connections are made. Typically, bridges connect LANs of identical topologies and access methods, running at similar or different transmission rates.

A gateway does not limit itself to the lower layers of the OSI model. Bridges require the interconnected LANS to have layers identical to layers 3 to 7 in the OSI model. However, different LANS usually do not obey these restrictions. Gateways are used for connections between dissimilar LANs, between devices on the same LAN that understand different higher-level protocols, and between LANs and long-haul networks of different architectures. Figure 4-8 illustrates the gateways connecting LANs through the use of all seven layers of the OSI model.

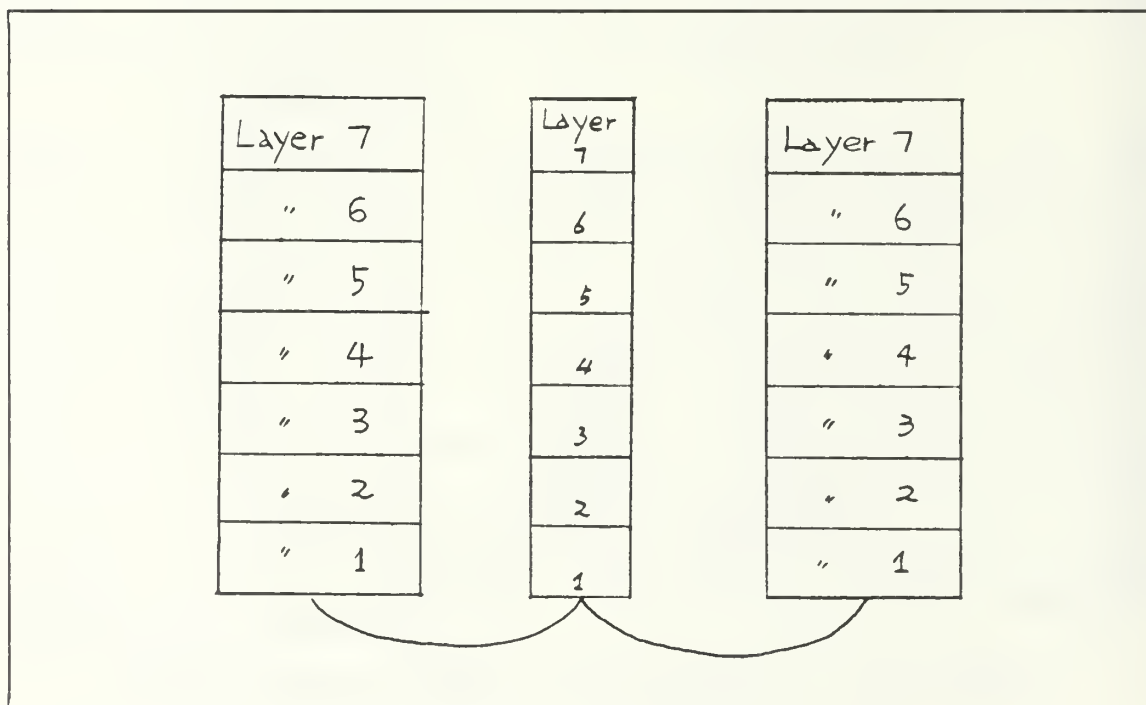


Figure 4.8 Connection of LANs through Gateways.

In addition to bridges and gateways, which interconnect two or more LANs, a large backbone LAN could be used to enable individual LANs to all have access through the backbone LAN. Figure 4-9 shows the environments where the LANs are interconnected [Ref. 4].

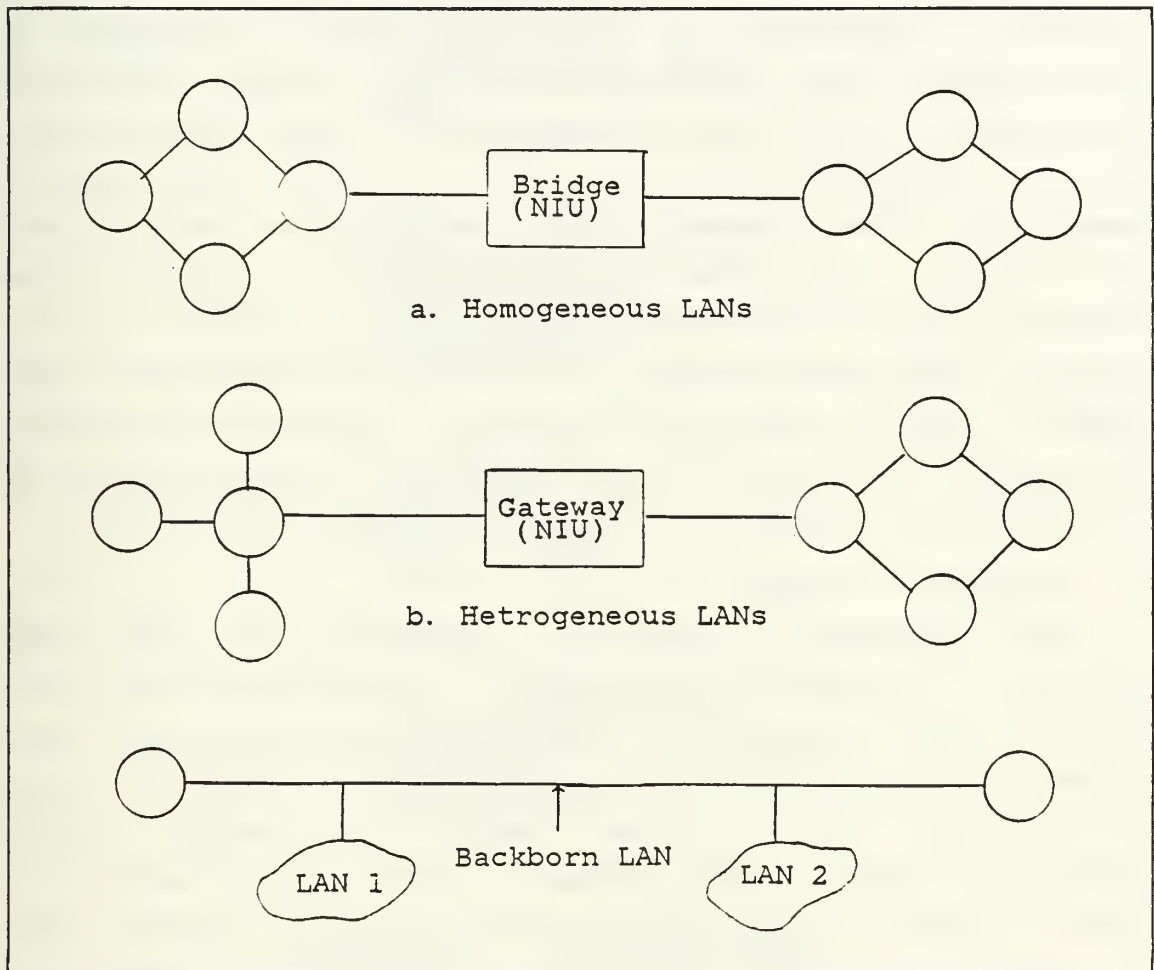


Figure 4.9 Types of Interconnection of LANs.

V. SOLUTION FORMULATION OF A LAN

A. INTRODUCTION

The purpose of this chapter is to select fundamental technical ingredients of a LAN by selection tree and an appropriate vendor associated with a specific operating environment. The design elements of a local area network must be carefully chosen in order to provide the required levels of data communication capabilities and network performance. Therefore, the first section of this chapter discusses the selection process such as access control method, transmission medium, topology and transmission techniques. Based on previous discussion, the following section will select the proper vendor for ROKM. The last section of this chapter presents the model of LAN required by ROKM.

B. SELECTION PROCESS

The fundamental technical ingredients of LANs are: topology, transmission techniques, transmission media and access control techniques. Manufacturers mix-and-match these ingredients to arrive at a LAN offering. Figure 5-1 shows the taxonomy tree. One can regard this taxonomy as four grab-bags where a LAN designer could choose one of the options from each bag to construct a LAN. The taxonomy shows the spectrum of choices within the LAN industry. Designing an LAN that satisfies user demands is not a simple process. It requires choosing an access control method, transmission media, topology and a transmission method. Next, we examine these choices critically and consider how standardization efforts and other factors will help potential LAN buyers narrow their options. In a military environment, we have to consider two types of military work: military oriented processes and office oriented processes. These two types of

military work should be treated appropriately through the network.

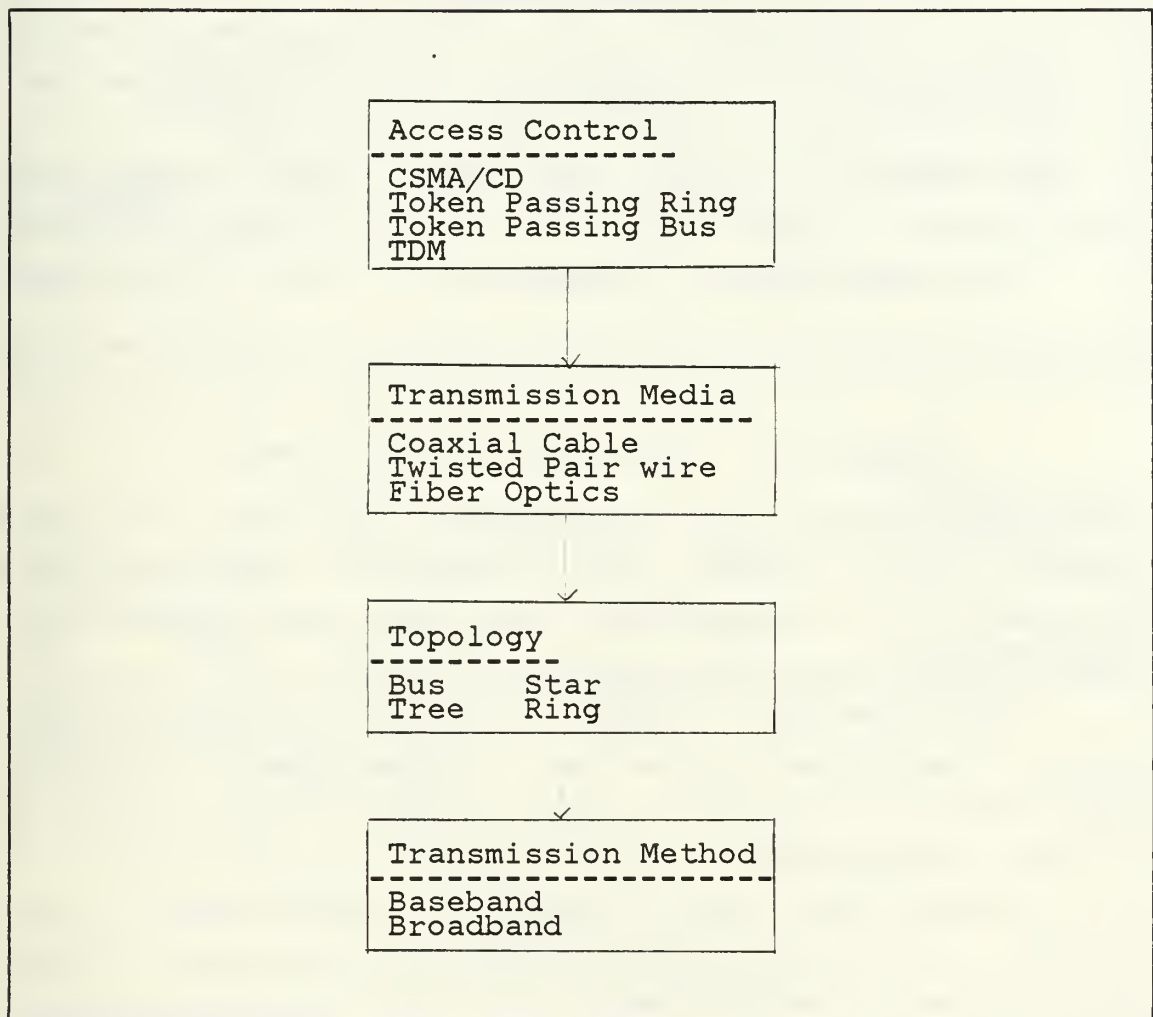


Figure 5.1 Taxonomy Tree.

1. Access Control Method

Each of the access control methods discussed in the previous chapter are in popular use today. The advantages and disadvantages of each have lead to what is called the "deterministic-probabilistic" controversy. Figure 5-2 illustrate the decision tree for access methods [Ref. 2].

TDMA, centralized polling, token passing ring and slotted ring offer "deterministic" access. In TDMA nodes are

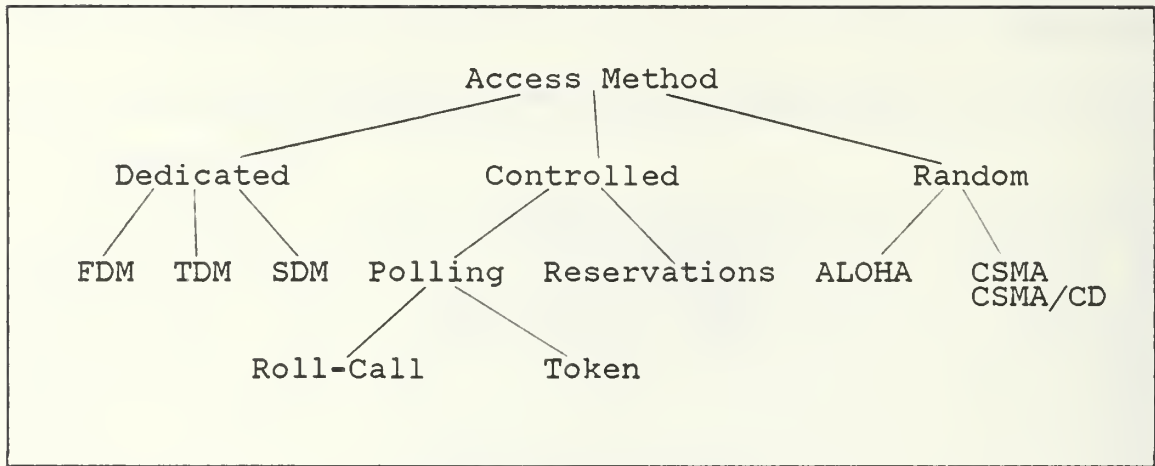


Figure 5.2 Decision Tree for Access.

given unique time slots during which they have exclusive command of the channel. The messages of many nodes are interleaved for transmission and then demultiplexed into their proper order at the receiving end [Ref. 4].

The advantage of TDMA is that the achievable bit rate of the medium exceeds the required data of a digital signal. Multiple digital or analog signals can be carried on a single transmission.

Centralized polling can be implemented in any topology, as well as in multipoint configurations. In each case, the master decides which node is to access the network at any one time.

Token passing and slotted ring offer "deterministic" access as well. As each station may hold the token for a specified maximum amount of time, every station in the LAN is guaranteed access.

In contrast, CSMA/CD offers "probabilistic" access. Since there no predetermined order access by nodes in CSMA/CD, there is no guaranteed maximum wait time before getting access to the channel.

The advantages of probabilistic access gives polling, token passing and slotted ring a marked advantage

for real time process control applications. Figure 5-3 [Ref. 7] is a selection tree to determine the optional access method for a specific operating environment. Since the buyer has to consider not only today's environments but also how the environment is likely to evolve.

To choose the appropriate access method for LAN, the prospective user can move from left to right across the selection process to see the transmission characteristics supported by the three most popular access techniques.

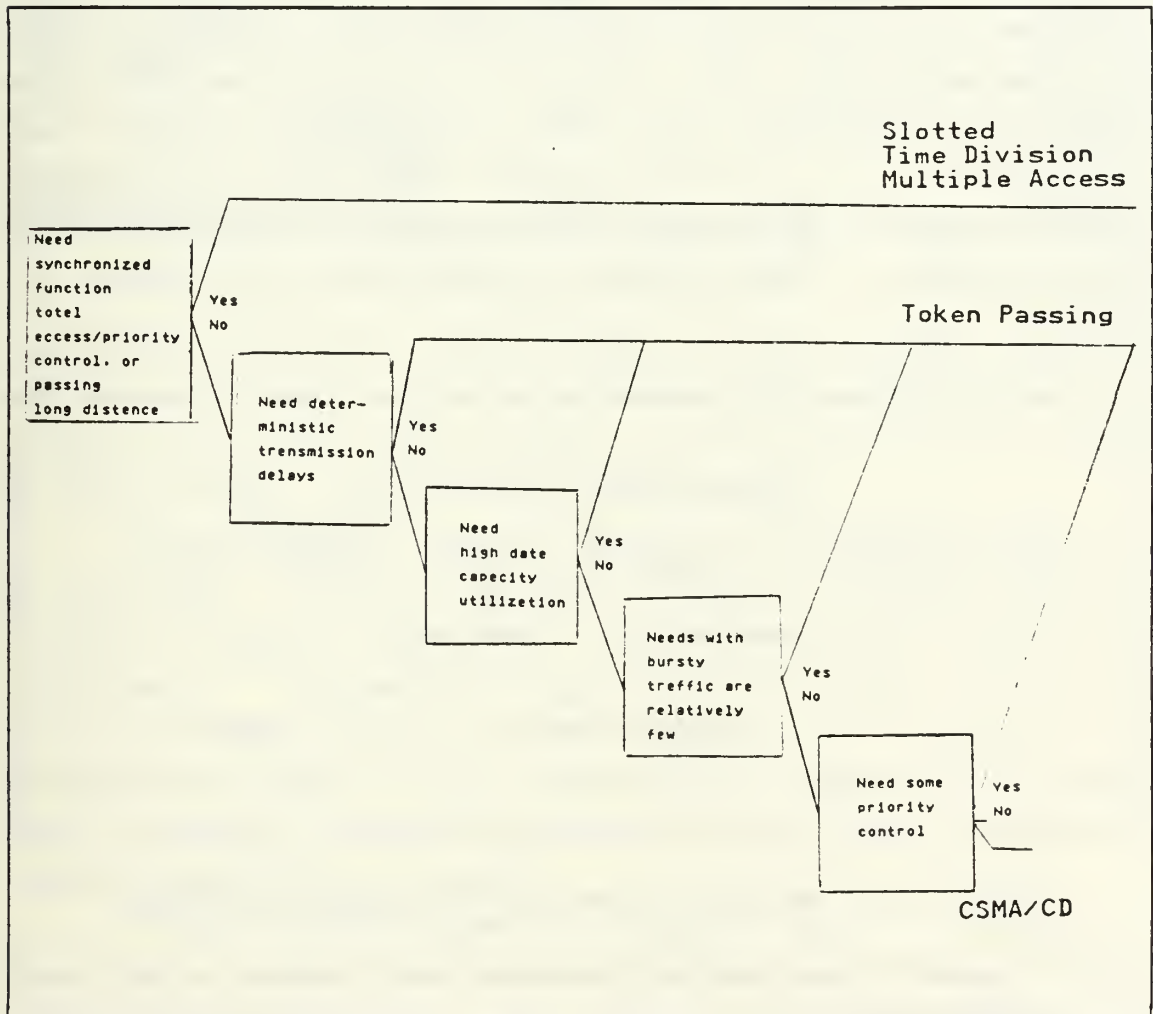


Figure 5.3 Selection Tree for Access Method.

The first process in selecting the access tree in figure 5-3 considers distance. The physical distance of ROKM between DOD and Air Force is approximately 8 KM.

Therefore, TDMA is appropriate, as can be seen by going from left to right through the product selection tree.

2. Transmission Medium

Transmission media [Ref. 3] provide the physical channel used to interconnect nodes in a network. Media are classified as bounded - that is, wires, cables and optical fibers; or unbounded - the "air waves", over which radio, microwave, infrared and other signals are broadcast. The unbounded media are good choices for point-to-point links between buildings, but since they are not well suited to LAN requirements. So, only the bounded media will be discussed in this thesis. The primary alternatives for transmission media utilized in LANs are the bounded media, as Figure 5-4 [Ref. 6].

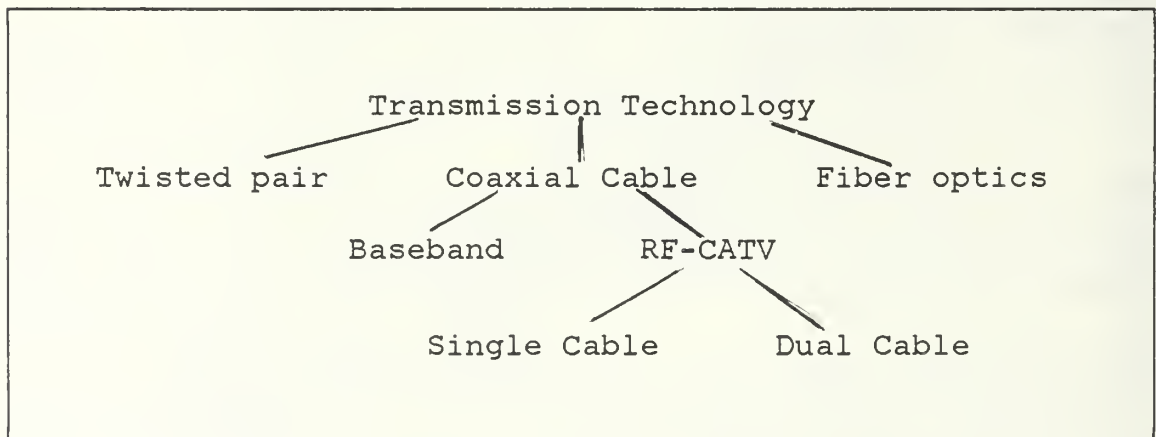


Figure 5.4 Decision Tree for Transmission Media.

Table II summarizes some of the important characteristics of the bounded media.

The ROK military LAN has several constraints in selecting a transmission medium. First, the maximum distance between two nodes is about 8 Km. Second, the types of

TABLE II
TRANSMISSION MEDIA FOR LAN

Medium	Singaling Technique	Maximum Data Rate (Mbps)	Maximum Range at Maximum Data Rate (Km)	Practical Number of Devices
Twisted pair	Digital	1 - 2	Few	10's
Coaxial cable (50 ohm)	Digital	10	Few	100's
Coaxial cable (75 ohm)	Analog with FDM	50	1	10's
	Single channel Analog	20	10's	1000's
Optical fiber	Analog	10	1	10's

information currently transmitted across the LAN are data and imagery. But, in the near future, HQs and DoD expect to transmit voice and video as well as the previous two things on the network.

Now it is the time to decide which medium to pick up for the LAN. Figure 5-5 [Ref. 7] shows product selection "trees" to determine the best medium for a user's operating environment. We can move from left to right across the selection "tree", checking the distances, bandwidth and applications supported by twisted pair, baseband and broadband. Optical fiber currently seems best only for point-to-point communications.

When the LAN expects to combine data, voice, and video, the choice a broadband coaxial cable which offers sufficient bandwidth to support all the types of transmitted information. When expecting to have only data and some limited voice capability, baseband coaxial cable may be selected. If a system needs a small, data-only network, install twisted pair wire may be installed.

Considering the characteristics of transmission media and constraints of designing the military LAN, and following the selection trees of Figure 5-5, we can select a broadband coaxial cable as transmission medium for the LAN.

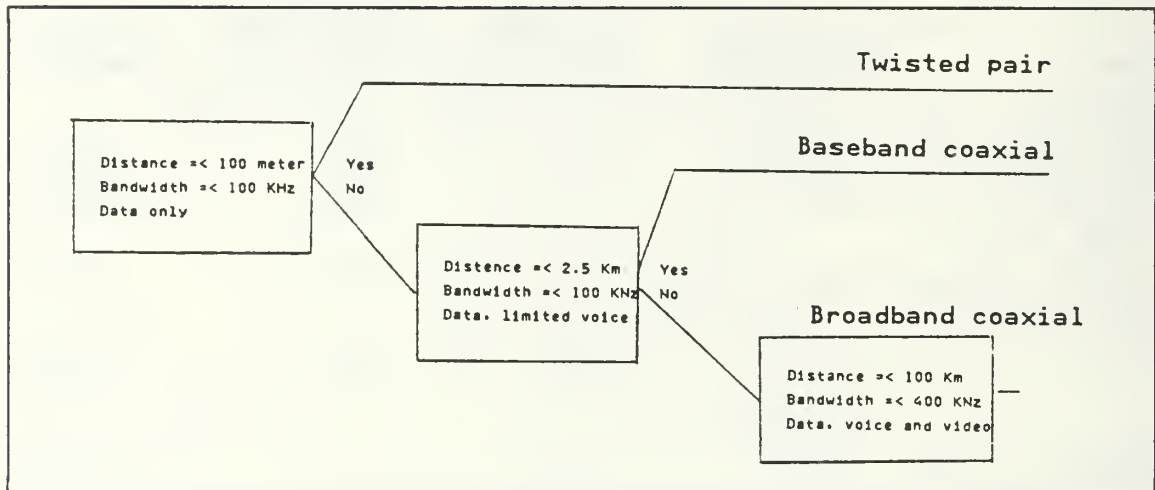


Figure 5.5 Section Tree for Transmission Medium.

3. Topology

The choice of topology, as illustrate Figure 5-6, depends on a variety of factors, including reliability, expandability and performance. We can opt for different topologies according to varying strategies for controlling the network.

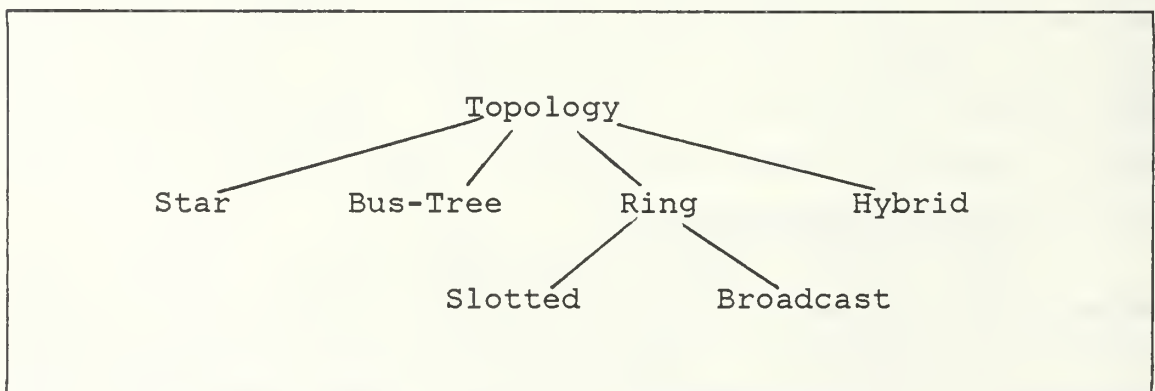


Figure 5.6 Decision Tree for Topology.

The two main strategies are centralized control and distributed control. With centralized control, access to the network and allocation of the channel are controlled by one node, such as a dedicated communications processor or switch. Distributed control is able to establish connections and access the network channel independently, according to an accepted set of rules. The advantages and disadvantages of topology are given below [Ref. 2] ;

- a) The bus/tree topology is able to handle a wide range of devices, in terms of number of devices, data rate, and data types. High bandwidth is achievable.
- b) The ring has the potential of providing the best throughput of any topology. But, there are some limitations in terms of numbers of devices and variety of data types. Furthermore, the reliability problem is obvious: single link or repeater failure could disable the entire network.
- c) The star topology lends itself well to low data rate ($\leq 64\text{KPS}$) devices. But, it is good for terminal-intensive requirements because of the minimal processing burden that it imposes.

The choice of transmission medium and topology are not independent. Table III shows the preferred combinations.

TABLE III
RELATIONSHIP BETWEEN MEDIUM AND TOPOLOGY

Medium	Topology			
	Bus	Tree	Ring	Star
Twisted	*	*	*	*
Baseband coaxial cable	*		*	
Broadband coaxial cable	*	*		
Optical Fiber			*	

After considering pertinent aspects of our military situation such as physical location, required types of data and security, we should choose bus topology since:

- a) maximum node-to-node is approximately 8 KM
- b) need to permit easy expansion

- c) need to handle a wide range of devices
- d) will support different types of data in the future

4. Transmission Techniques

The debate over which is the best of the two transmission techniques--baseband and broadband--continues to be a popular topic in conferences and the trade press. Baseband partisans argue that lower cost, simplicity in implementation, higher transmission speeds and lower maintenance requirements make it the clear winner. Broadband advocates point to its support of more users in a LAN over longer distances, plus its ability to multiplex audio, video and data transmission.

In actual fact, the two transmission techniques are suited for different applications. Baseband satisfies the need to interconnect devices within one office or department. Users can most benefit from the higher transmission speeds offered by baseband LANs; their lack of video or audio capability is not important, due to the close proximity of the users to each other.

Broadband is better adapted for communication between larger complexes of offices and building. We can put more users on a broadband LAN, but the trade-off is lower speed transmission. It can also carry video and audio signals between disparate locations for teleconferencing and other similar applications. Table IV shows the pros and cons of the two techniques [Ref. 2].

So far, we have examined the characteristics and pros and cons of baseband and broadband systems. When we consider the requirements of the ROK military LAN - long distance (8 Km) between two nodes and multiple traffic types (video, voice and data), we can select broadband as a transmission technique for the LAN.

TABLE IV
BASEBAND VERSE BROADBAND

----- Advantage	Disadvantage -----
Baseband	
Cheaper - no modem	Single channel
Simple technology	Limited capacity
Easy to stall	Limited distance
Broadband	
High capacity	Modem cost
Multiple traffic type	Installation and maintenance complexity
More flexible configuration	Doubled propagation delay
Large area coverage	
Mature CATV technology	

C. LAYOUTING AND CHOOSING A LAN

Through previous sections, we chose the four fundamental technical elements of designing LANs. In consequence, we selected a broadband local area network. Broadband local networks use frequency division multiplexing (FDM) to divide a single physical channel made of coaxial cable into a number of smaller independent frequency channels. Hence, all signals on the broadband LAN are analog, and digital data signal must be converted to analog in order to be transmitted. The separate channels created by FDM can support different types of data - specifically voice, data and video with different bandwidths and thus, broadband LANs are considered multifunction networks. For all practical purposes, they can allow several separate networks to operate simultaneously or one physical network channel.

Broadband components allow splitting and joining operations, hence both bus and tree topologies are possible.

The technology used for broadband LANs--the coaxial cable, as well as the components used to interface to the cable and split it into branches--is essentially the same as that used for CATV, commonly known as cable TV. Broadband technology is also used for video conferencing and security operations within organizations.

1. Transmission Medium

Coaxial cable (75-ohm cable) is used as the transmission medium for broadband LANS because of the characteristics it offers, particularly [Ref. 4] ;

- Capacity - readily available, low-cost standard CATV coaxial cable provides bandwidths of 300 to 400 MHZ.
- Performance - High speed data transmission rates and very low bits error rates (one bit error per every 10^{*8} to 10^{*11} bits).

2. System Configuration

A broadband network operates over long distances, has a flexible topology, carries mixed-media services and uses standard transmission components. But even if all these factors contribute to selection, implementation issues such as whether to use single or dual cable distribution remain to be solved.

All broadband LANs function in a similar manner: transmitted carrier signals are sent to a headend (inbound), from which they are retransmitted to all points on the network. Physically, two different cable schemes are used to implement the inbound and outbound (Figures 4-3b and 4-3c): single cable and dual cable. In the dual cable configuration, a network uses one cable for the inbound path and the other for the outbound path. The paths are separate cables, with the headend simply a passive connector between the two. Stations send and receive on the same frequency.

By contrast, single-cable systems employ only one cable, which uses a frequency-spectrum split to achieve bidirectional communications. Bidirectional amplifiers pass lower frequencies inbound and higher frequencies outbound.

The headend contains a device, known as a frequency converter, for translating inbound frequencies to outbound frequencies.

Split systems [Ref. 8] are categorized by the frequency allocation to the two path: the available frequency range is split into a "return" band (from the user to the headend) and a "forward" band (from the headend to the users). Three frequency splits are possible: subsplit, midsplit and highsplits.

- a) Subsplit - The total bandwidth of the return path is 25 MHz and the bandwidth of the forward path is 346 MHz (given a normal 400 MHz). Sub-split has been the most popular scheme with the community.
- b) Midsplit - The bandwidth of the return path is 103 MHz, and the bandwidth of the forward path is 226 MHz equaling 329 MHz of total available bandwidth. For LANs, the midsplit format has been the most popular because of greater available bandwidth for the return path. This increased band pass allows for more duplex data communications links. In addition, IEEE committee 802 has endorsed the midsplit format until a new highsplits format is formally adopted.
- c) High split - This format, also called 'supersplit' or 'equalsplit', divides the available bandwidth into two equal portions for the forward and return paths. The return bandpass is from 5 to 175 MHz and the forward bandpass is from 232 to 400 MHz. The advantage of highsplits is an increased return-path allocation. However, none of the high band VHF channels (7 through 13) are available for highsplits formats, since these frequencies fall into the guard band, which separates forward and return channels. Highsplit networks are more appropriate for pure data communications applications than for mixed node services.

Figure 5-7 illustrates the frequency allocation for each [Ref. 8]. When the three split formats are compared with each other, midsplit can be adopted to support the environment of ROK military LAN.

The differences between split and dual are minor but important to design or select a physical LAN. Studies [Ref. 8] indicate that an average of only 35 % of the total available bandwidth is currently being used in broadband local networks. There are exceptions but generally only about 60 MHz in each direction is required to meet the current needs of most local networks for data, video, audio

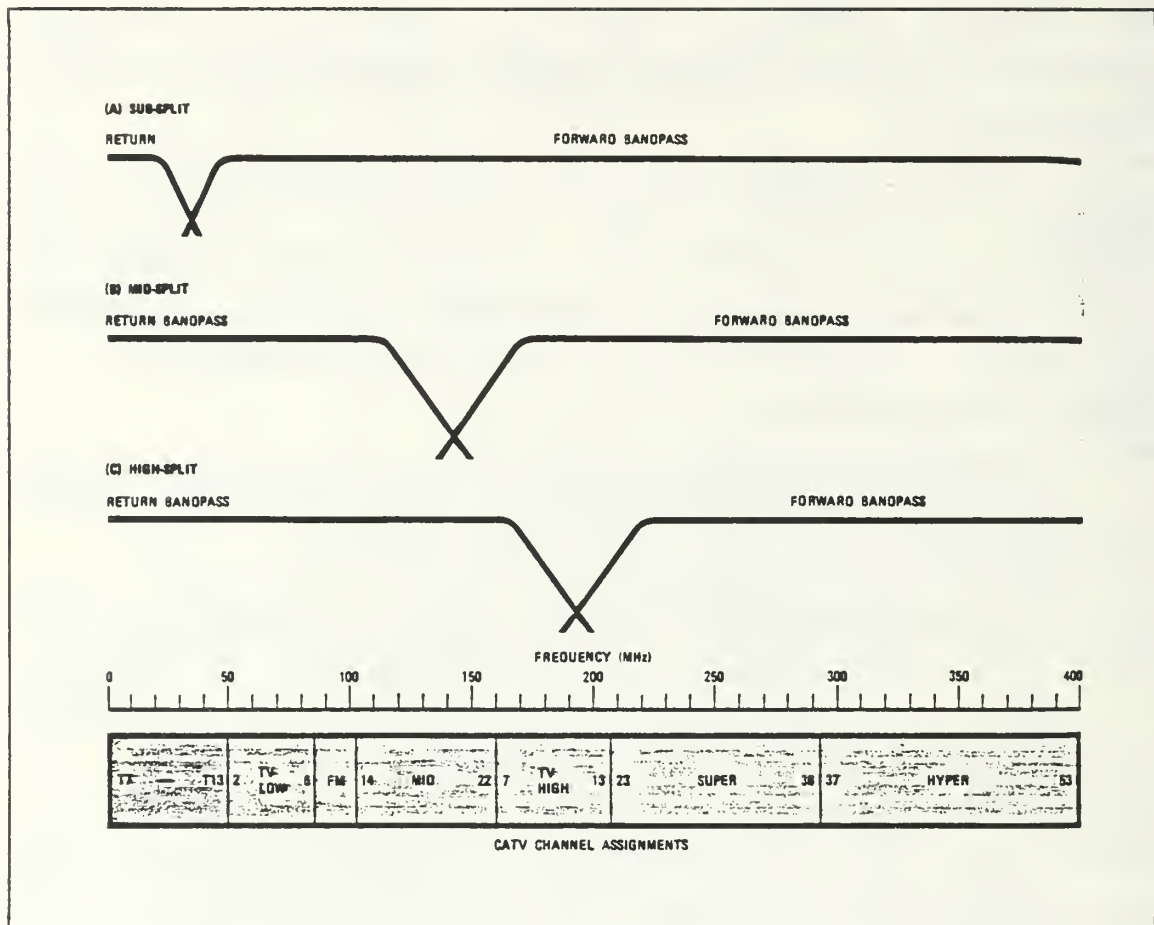


Figure 5.7 Frequency Allocation of the Three Split Formats.

and control. In a direct cost analysis, it takes more than 150 MHz of bandwidth before dual-cable systems offer a cost/bandwidth advantage over single-cable distribution.

Dual-cable LANs are less cost-effective than single-cable LANs, since they need twice the hardware--cable and amplifiers--to support the same number of outlets. In addition, it may be difficult to find the required space to mount or service all the dual cable LAN components.

Maintenance requirements for both systems are very low due to the high reliability and mean time between failures of the RF components.

Single cable LANs can be represented as a branching tree, which simplifies network design and also facilitates network maintenance. It is easy to trace such a topology. Dual-cable LANs become more of a headache, since the loop must be maintained throughout the network.

Noise accumulation on a dual-cable network is perpetuated from the inbound cable to the outbound cable. As a result, dual-cable LANs are not ideal for a large campus environment or among multiple buildings unless the headend is configured so that the inbound and outbound cables are separated.

Table V summarizes and compares the characteristics of both systems. Dual cable systems have been used for many years. However, technology, cost and installation considerations favor single-cable topologies for the distribution of RF signals in data processing, video, control and audio applications.

TABLE V
SUMMARY OF CHARACTERISTICS OF SINGLE AND DUAL CABLE SYSTEMS

System	Single	Dual
Cost/bandwidth	Advantageous	Inefficient
Hardware/Space	Cost-effective	Twice than single
Network maintenance	Easy due to simple configuration	Difficult to trace
Noise accumulation	Possible to eliminate	Perpetuated if the two paths separate

3. Implementation

A single cable broadband system uses standard, off-the-shelf CATV components, including 75-ohm coaxial cable. All end points are terminated with a 75-ohm terminator to

absorb signals. The main components of the systems are cable, terminators, amplifiers, directional couplers and controllers (Appendix D). Figure 5-8 illustrates the typical single cable topology [Ref. 9].

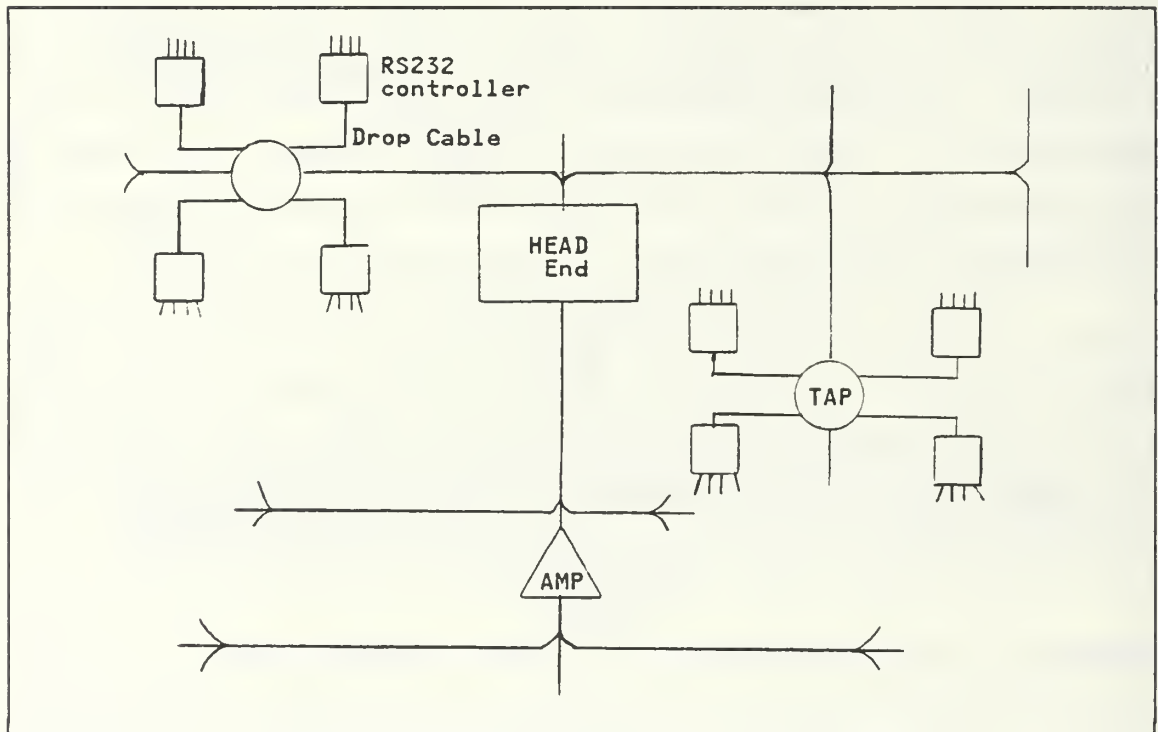


Figure 5.8 Single Cable Topology.

When we consider the military environment, a backup to crucial network services is required in case the primary network is damaged. Therefore network redundancy is desirable. Services must be recovered as soon as possible. Using a midsplit single-cable network, two independent cables can be installed side by side, providing the redundant communications path. The implementation of such a network is simpler with only two cables in the ceilings of each office. Figure 5-9 [Ref. 8] illustrates the redundant trunks. A reliable and practical solution to redundancy is to install two independent midsplit trunks with RF switches located at each building entrance. In this way, only the trunk network

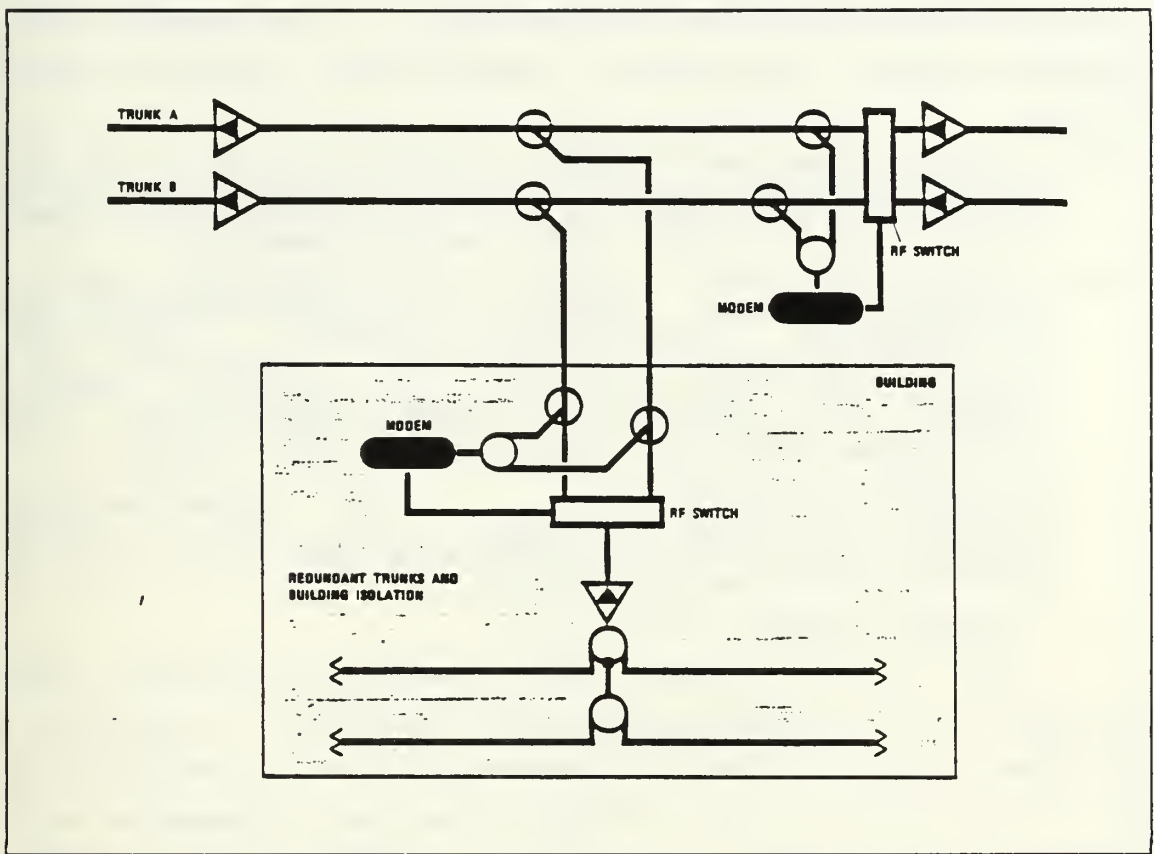


Figure 5.9 Redundant Trunk Topology.

is redundant. With this arrangement, the full bandwidth of both trunks is divided among two service classes at the building interface. The first class could be essential or high priority services that require guaranteed availability. The second class would be nonessential services.

Through a polling scheme, the trunks can be monitored and switched either automatically or manually. This facilitates examination of each network sector for intentional or unintentional signals that may interface with network operations. If any problems are encountered, individual sections can be isolated from the main network and repairs made without bringing down the whole network.

As mentioned earlier, the broadband LAN can be used to carry multiple channels, some used for analog signals,

such as video and voice, and some for digital. Three kinds of digital data transfer services [Ref. 2] are possible on a broadband cable: dedicated, switched and multiple access service.

- a) Dedicated service - A small portion of the bandwidth is dedicated for exclusive use by the two devices. The two devices are connected with the cable through each modem which is tuned to the same frequency.
- b) Switched service - A number of channels are used for switched service. Devices are connected with the cable through "frequency agile modems". Initially, all attached devices, together with a controller, are tuned to the same frequency. If a station sends a request for connection to the controller, the controller assigns an available channel to the two devices and tunes the modems to the same channel.
- c) Multiple access service - A number of devices are turned at the same frequency. Some form of medium access control protocol, TDMA with reservation will be used for ROK military LAN (Appendix D).

4. System Layout

Up to now through this chapter, we dealt with choosing the fundamental technical elements of designing a LAN. Then a single midsplit broadband system was selected as the LAN for ROK military. Using the basic components of a broadband cable system, the layout of the military LAN can be drawn as in Figure 5-10.

D. STANDARD

A standard for local area network is being developed by IEEE local network committee. The stated objective of the local network standard [Ref. 10] is to ensure compatibility between equipment made by different manufactures such that data communications can take place between the devices with a minimum effort on the part of the equipment users or the builders of a system containing the equipment. To accomplish this, the standard will provide specifications which establish common interfaces and protocols for local area data communications networks. Standards serve as a frame of reference in design choices.

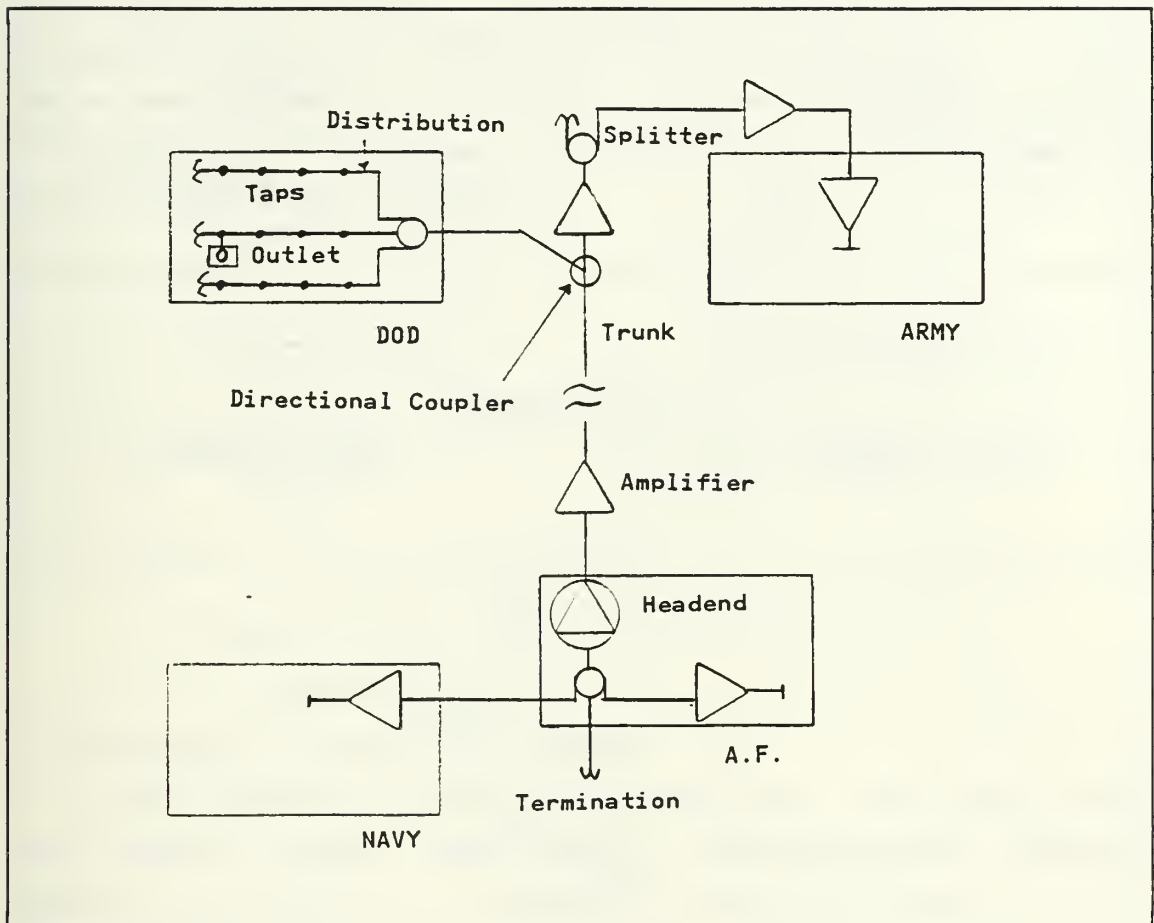


Figure 5.10 Layout of Military LAN.

1. Media Independence

The IEEE 802 local network standard specifies a media independence to be flexible enough to allow different types of physical interconnection means depending on the specific needs of a customer's application or of his environment. It is therefore desirable to specify a 'media-independent' interface to the network. This architecture can be illustrated as shown in Figure 5-11.

In order to achieve media independence, a device called a 'media access unit' must be defined. This device converts the electrical or optical signals which are carried by the 'main' network medium (designated by p) into a

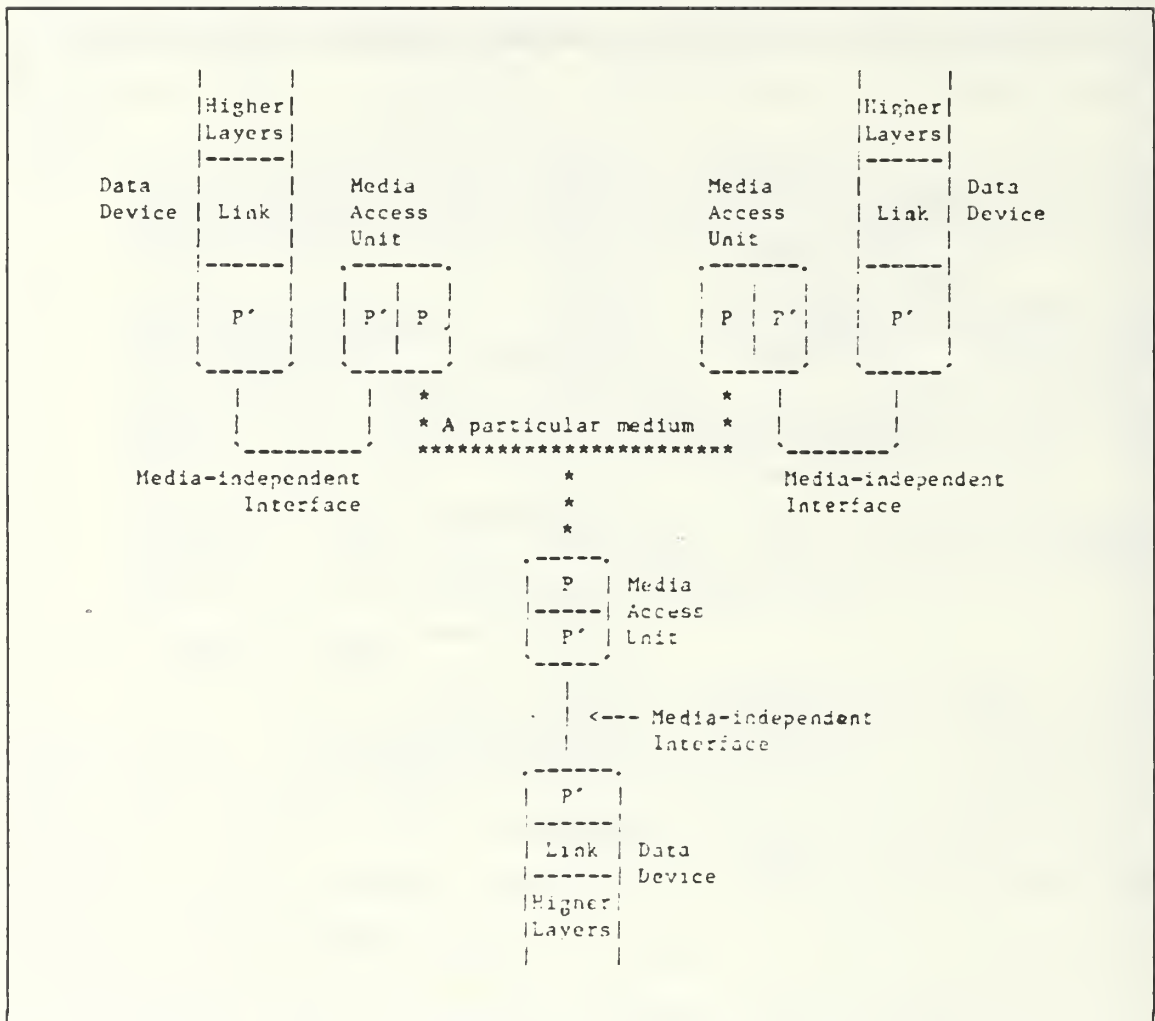


Figure 5.11 the Architecture of a Local Network Connection.

standard form which is understood by all devices connected to the network (designated by p').

2. Channel Allocation (IEEE 40.1)

The IEEE 802 local network standard [Ref. 12] specifies a single cable using a "mid-split" configuration. Mid-split refers to the frequency spectrum from 5 to 300 MHz, with 5 to 108 MHz reserved for the inbound frequencies and 162 to 300 MHz reserved for outbound frequencies. A typically band-allocation scheme is shown in Figure 5-12. The frequencies between 108 and 162 MHz are reserved as a

guard band to prevent interference between the two major frequency bands. In order for this to be possible, single-cable systems require a device, called a headend or Central Retransmission Facility to translate or remodulate send signals into receive signals.

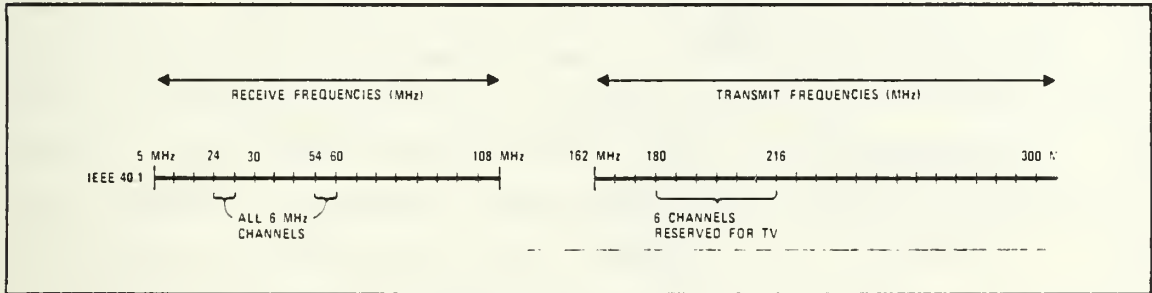


Figure 5.12 IEEE 40.1 Band-allocation.

E. CHOOSING A LOCAL AREA NETWORK

In the previous chapter and sections, we chose desired LAN design elements and examined some required standard. Appendix E provides a comparison of major broadband vendor's products [Ref. 12].

Based on the specifications of the real requirements of ROKM's LAN and access control, transmission media, topology and transmission methods already selected, we can choose AMDAX SERIES 7 or SERIES 14 of the products provided by different vendors since they meet all requirements:

- 1) broadband
- 2) access method: TDMA with reservation (see Appendix F)
- 3) coaxial cable
- 4) network transfer rate: more then 7 M bit/sec
- 5) bit error rate 10^{-8}
- 6) interface: RS-232-C
- 7) standard [Ref. 9]
 - adheres to the proposed IEEE 802 physical standards
 - supports a version of the proposed IEEE 802 LNLLC standard for link control (see Figure 5-13) [Ref. 9]

- as regard to the IEEE 40.1 band-allocation standard, AMDEX is in close conformity (see Figure 5-14) [Ref. 12]

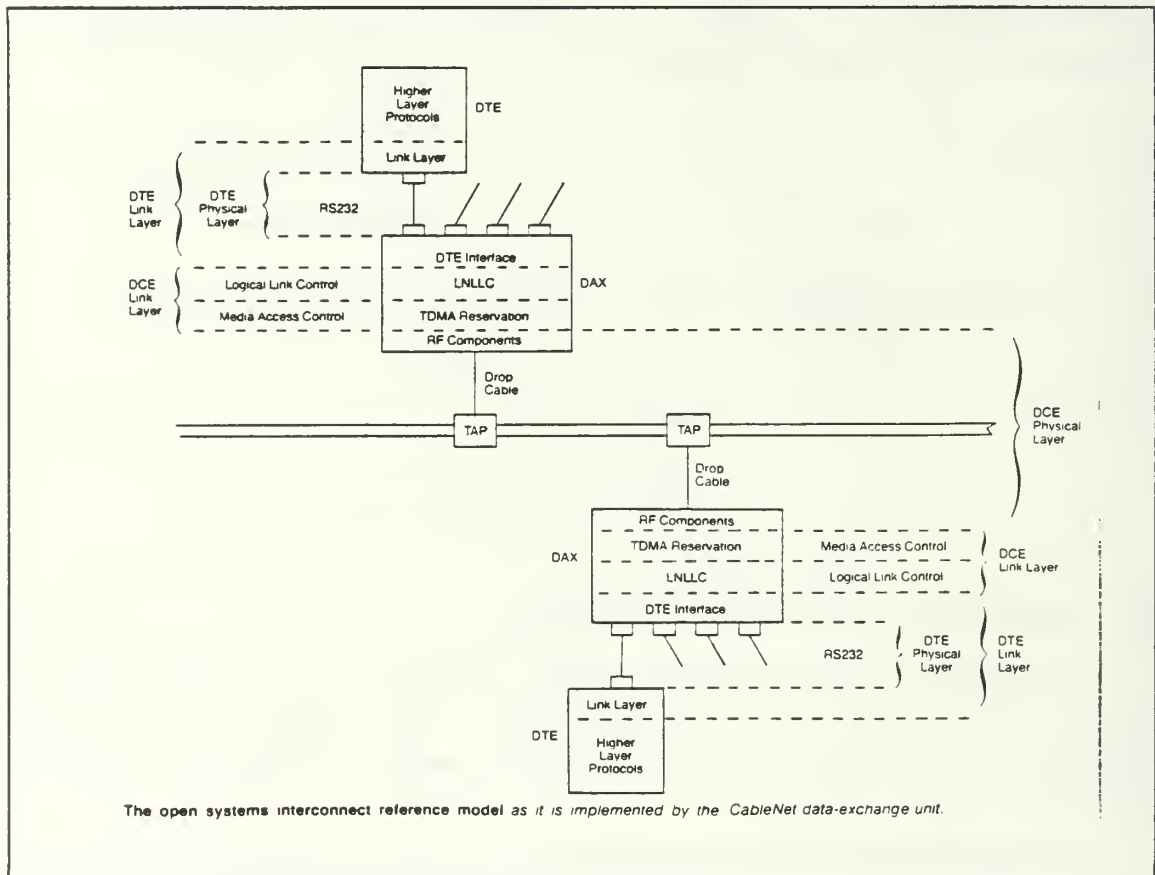


Figure 5.13 Communication Standard.

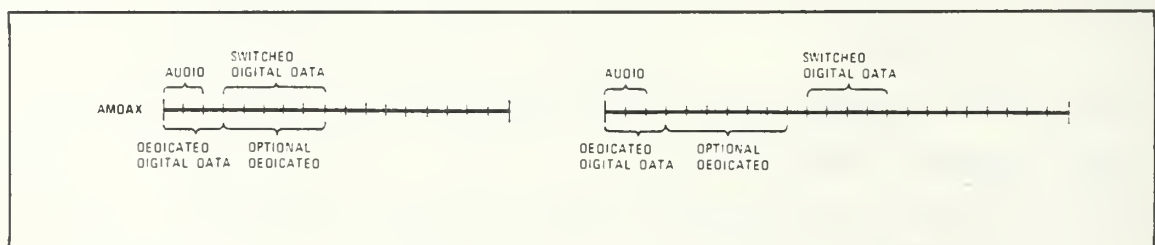


Figure 5.14 AMDEX Band-allocation.

VI. CONCLUSIONS AND RECOMMENDATIONS

This thesis was an attempt to provide the key elements and guidelines for designing a LAN among the three HQs and the DoD. The first part of this study provided a broad overview of the system, how it functioned and what its existing facilities were. Following a review of the overall system, user requirements were identified and analyzed. The requirements statement included information production, information transmission and information management. That statement was utilized to express those concepts in a manner which would aid designers in understanding the system.

User requirements were identified and expressed in terms usable by systems designers and then, several LAN requirements were developed. Those requirements represented needs necessary which would satisfy the identified user requirements. The LAN requirements included those such as software, information types transmitted on the network, security, reliability, interconnection of LANs and interfacing. After LAN requirements were identified and analyzed, evaluation criteria were established as guidelines to design the LAN and the model of the system was represented by Data Flow Diagram (DFD) and Data Dictionary (DD).

In the second portion of the thesis, major technical issues, concepts and characteristics, necessary to design the LAN, were examined. The issues addressed included topology, access control methods, transmission media, transmission techniques, communications channels, communications standards and LAN components.

Third, pros and cons, and characteristics of the four fundamental technical elements were interrelated and were compared with requirements and evaluation criteria. A taxonomy and three selection trees were used to select the

technical elements. The taxonomy tree showed the spectrum of choices within the LAN market. The selection trees showed the factors that must be considered to choose each technical element. The factors included distance between nodes, bandwidth, data types transmitted on the network, traffic quantity, and access priorities.

As a consequence, it was selected and recommended those things such as following; TDMA with reservation was selected as the access control method, broadband coaxial (75 ohm) as the transmission medium, bus as the topology for the LAN, and a single-cable, midsplit broadband as the transmission technique. Then, AMDEX (series 7 and 14) was chosen as a vendor capable of providing the LAN necessary for the ROK military requirements.

It is expected that this study can serve as a guideline or partial solution for constructing the LAN to connect the HQs and DoD. Detailed installation, implementation, testing and loading of the LAN awaits further research.

APPENDIX A

SWITCHING TECHNIQUES

1. CIRCUIT SWITCHING

Circuit switching, the predominant method used for establishing telephone connections, is the basis of communications in worldwide telephone networks today. In circuit switching [Ref. 2], every time a call is generated, there is a physical connection between two stations. Communication via circuit switching involves three phases:

- 1) Circuit establishment: The proper electrical path or circuit must be established and switched into the network to provide an interconnection between the two stations before any data can be transmitted.
- 2) Data transfer: After the connection is established, the use of the path is exclusive and continuous for the duration of data transfer.
- 3) Circuit disconnect: When the data transfer is completed, the circuit is disconnected, usually by the one of two stations and restored to readiness for other connections by the switching node.

Circuit switched messages usually establish a totally new channel between two stations every time a call is originated. Circuit switching can be rather inefficient. Bursty computer-to-computer communications and character-by-character terminal communications illustrate the inefficiency of circuit switching for data transmission. In both cases, the line could be idle for a significant portion of the connection time, yet remain unavailable to other users. When data transmissions are relatively long, the setup time required to establish circuits can be offset by the amount of time the channel is used. However, for transmissions which are shorter, circuit switching is slow, relatively expensive and inefficient. Once a circuit-switched connection is made, however, there is no delay and communications take place in real time.

2. MESSAGE SWITCHING

Message switching developed as the computer solution to message exchange. As stated, circuit switching developed as a solution to the need for exclusive, continuous, temporary connections in order to transmit voice conversations. In message switching, it is not necessary to establish a dedicated path between two stations. If a station has a message and wants to transmit it, it appends a destination address to the message. Message switching is the process by which messages are placed on the channel and travel across the network to their destination. In circuit switching, the channel established for transmission is completely independent of the message being sent. Messages, on the other hand, contain the addresses of their ultimate destinations.

When the message is passed through the network, each node receives, stores briefly, and transmit it to the next node. Communications via message switching uses a store-and-forward message system. A number of advantages of this approach over circuit switching are listed below [Ref. 2]:

- 1) line efficiency is greater, since a single channel can be shared by many messages over time.
- 2) simultaneous availability of sender receiver is not required.
- 3) in heavy traffic on the network, messages are still accepted with delivery delay increased - not blocking some calls.
- 4) one message to many destinations.
- 5) message priorities can be established.
- 6) error control and recovery procedures.
- 7) a message-switched network can carry out speed and code conversion.
- 8) messages sent to inoperative terminals may be intercepted and either stored or rerouted to other terminals.

The primary disadvantage of message switching is that it is not suited to real time or interactive traffic. The delay through the network is relatively long and has relatively high variance. Thus it can not used for voice connections. Nor is it suited to interactive terminal-host connections.

APPENDIX B

THE OSI MODEL

The OSI model is protocols for data communications proposed by International Standard Organization (ISO). The seven layers of the OSI model are explained below.

1. PHYSICAL LAYER

The physical layer defines the electrical and mechanical aspects of interfacing to a physical medium for transmitting data, as well as setting up, maintaining and disconnecting physical links. When implemented, this layer includes the software device driver for each communications device plus the hardware itself - interface devices, modems and communications links. The most common standard in use today is RS-232-C.

2. DATA LINK LAYER

The data link layer attempts to make the physical link reliable and provide the means to activate, maintain and deactivate the link. It establishes an error-free communications path between network nodes over the physical channel, frames messages for transmission, checks integrity of received messages, manages access to and the use of the channel and ensures proper sequence of transmitted data.

3. NETWORK LAYER

The network layer is designed to facilitate communication between systems across a communications network. It addresses messages, sets up the path between communicating nodes, routes messages across intervening nodes to their destinations and controls the flow of messages between nodes.

4. TRANSPORT LAYER

The transport layer and above of the ISO model are generally referred to as the higher layers. Protocols at these levels are end-to-end and are not concerned with the details of the underlying communications facility. The purpose of transport layer is to provide end-to-end control of a communication session once the path has been established allowing processes to exchange data reliably and sequentially, independent of which systems are communicating or their location in the network.

5. SESSION LAYER

The session layer establishes and controls system-dependent aspects of communications sessions between specific nodes in the network and bridges the gap between the services provided by the transport layer and the logical functions running under the operating system in a participating node.

6. PRESENTATION LAYER

Encoded data that has been transmitted is translated and converted into formats which enable display on terminal screens and printers - forms that can be understood and directly manipulated by users.

7. APPLICATION LAYER

Services are provided that directly support users and applications tasks and overall system management. Examples of services and applications provided at this level are resource sharing, file transfers, remote file access, database management and network management.

APPENDIX C

NETWORK INTERFACE UNIT

1. COMMUNICATIONS INTERFACE UNIT (CIU)

The CIU [Ref. 4] is the interface between the medium and the BIU. Two familiar forms of CIUs are modems - most often used in broadband LANs and PBX and transceivers used in baseband LANs. The actual physical connections from the CIU to the medium are made in a variety of ways by Media Access Units (MAUs). Most often the MAU is some form of cable tap from which a wire is run to the CIU.

The implementation of CIU functions is dependent on network configuration and design. For instance, in a network with centralized control, the CIU could be a simple modem that amplifies and modulates signals to their appropriate frequencies, creating a point-to-point connection between the device and a central controller. In such a case, most of the logic necessary for controlling and accessing the network, for instance for a polling or TDM scheme, is contained in a control computer or switch. An example would be a star network like a PBX. In a distributed network, most commonly ring or bus configurations, the major portion of network interface logic is placed in the CIU hardware and firmware to give each node the control of access to the network.

In a network with distributed control, the CIU monitors the network channel for message traffic to determine if it can transmit the message of its node. Monitoring could take the form of recognizing the control token in a token passing ring, or noting the absence of transmissions or collisions on a contention-oriented bus network. In addition, the CIU recognizes its node address, accepts messages addressed to

it, and transfers than to the station specific interface (the BIU, below). In a ring network, the CIU most often must repeat messages addressed to other nodes and pass on the tokens.

The CIU translates signals from the station interface into the form and format appropriate for transmission over the medium - for example, from digital to analog, or from parallel to serial, and vice versa. It is also responsible for driving the message over the medium, for power and ground isolation and for error detection at the physical and data link levels. Network control functions implemented in CIU hardware (and firmware) components are most often those of the physical and data link network layers.

2. BUS INTERFACE UNIT (BIU)

The BIU [Ref. 4] is the interface between the station's internal bus and the CIU. Figure C-1 illustrates the relationship among CIU, BIU and device [Ref. 4].

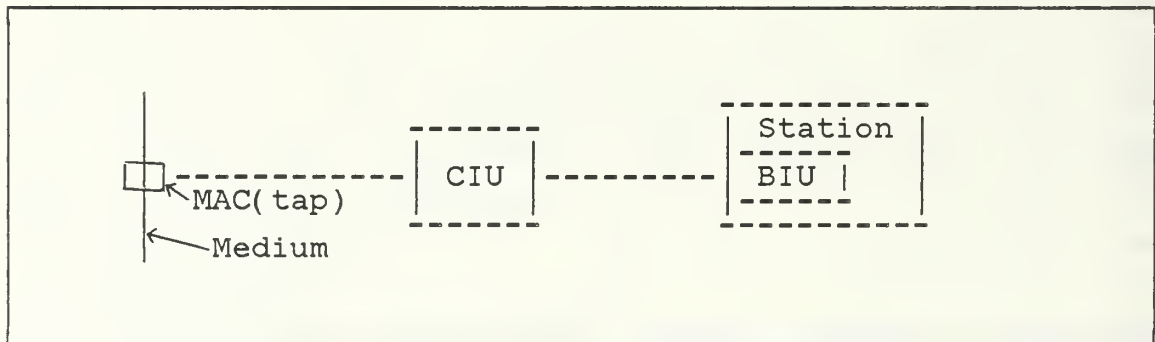


Figure C.1 The relationship among interfaces for LAN.

When simple low-speed devices like terminals and printers are connected to modems, the BIU can conform to industry standards (such as RS-232-C or CCITT V.24) in terms of physical connection and electrical interface. In such cases, the BIU might be a programmed or interrupt-driven I/O interface.

BIUs for more complex devices, such as processors or mass storage peripherals, interact with vendor-specific network control software functions. Such BIU hardware is designed specifically for the devices of a particular vendor. An example of such a BIU device would be a sophisticated Direct Memory Access (DMA) interface.

APPENDIX D

MAIN COMPONENTS OF BROADBAND SYSTEM

Cables [Ref. 2] used in broadband LANs are of three types: trunk, distribution and drop cable. Trunk cable forms the spine of a large LAN system and typically ranges in length from a few Km to tens of Km. Distribution cables are used for shorter distances and for branch cables. Drop cables are used to connect stations to the LAN.

Amplifiers may be used on trunk and distribution cables to compensate for cable attenuation. For single cable systems, amplifiers must be bidirectional, passing and amplifying lower frequencies in one direction and higher frequencies in the other.

Directional couplers or taps provide a means for dividing one input into two outputs and combining two inputs into one output. Splitters, used to branch the cable, provide roughly equal attenuation along the split branches. The broadband tap [Ref. 9] is a passive directional coupler that provides a mechanical interface between the trunk and the drop cable. The maximum length between the tap and the modem is 50m.

APPENDIX E

TDMA WITH RESERVATION

Time [Ref. 2] is organized into cycles, each cycle consisting of a set of equal-size time slots, and each time slot is sufficient for transmitting one frame. At the conclusion of one cycle, other cycle begins. From the point of view of the station, if the station has small message to send, it sends it in the next available unallocated frame on the inbound channel. To send messages too big to fit into a single frame, a station may reserve time on bus. when confirmation is received, the station assumes that its reservation suffered a collision and tries again. Various techniques are used for detecting collisions in reserving slots.

From the point of view of the central controller, communication is as follows. Frames are received one at a time on the inbound channel. Associated frames are repeated on the outbound channel with no further processing. If the frame is garbled or contains an error, it is ignored. If it is a valid data reservation frame, the controller fills the reservation within the limits of its available frames in the future cycles and sends a confirmation.

APPENDIX F

BROADBAND PRODUCT COMPARISON

MANUFACTURER/ PRODUCT	AMDAK SERIES 2/722	AMDAK SERIES 2/746	AMDAK SERIES 2/1148	AMDAK SERIES 7	AMDAK SERIES 14
TRANSMISSION SUPPORTED	AUDIO	DIGITAL DEDICATED	DIGITAL DEDICATED	DIGITAL SWITCHED	DIGITAL SWITCHED
NETWORK TRANSFER RATE	N/A	19.2 KBIT/S	56 KBIT/S	7 MBIT/S	14 MBIT/S
PORT SPEEDS	N/A	100 150 300 600 1.2K 2.4K 4.8K 9.6K 14.4K & 18.2K BIT/S	56 56 KBIT/S	110 300 600 1.2K, 2.4 4.8K 8.8K, & 19.2K BIT/S	110 300 600 1.2K, 2.4 4.8K 8.8K & 18.2K BIT/S
ACCESS METHODS	FDM	FDM	FDM	TOMA RESERVATION	TOMA RESERVATION
NO. OF 6-MHz CHANNELS USED (TRANSMIT/RECEIVE)	2/2 ⁽¹⁾	8/9 ⁽¹⁾	3/3 ⁽²⁾	1/1	2/2
HALF DUPLEX SUPPORT	N/A	ASYNCH. BSC	SYNC	SYNC, BSC	SYNC, BSC
FULL DUPLEX SUPPORT	ONLY	ASYNCH. BSC	SYNC	ASYNCH. SOLC/ HOLC	ASYNCH. SOLC/ HOLC
NO. OF PORTS PER UNIT	1	1	1	4	4
NO. OF CONTROL PORTS	N/A	8	8	1 ⁽⁴⁾	1 ⁽⁴⁾
AGGREGATE DATA RATE	N/A	N/A	N/A	38.4 KBIT/S	38.4 KBIT/S
INTERFACES	STD. TYPE 500 PHONE SET	RS-232-C	CCITT V.36	RS-232-C	RS-232-C
OPTIONAL INTERFACES	N/A	N/A	WE 383	RS-448	RS-448
MOUNTING	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT
MODULATION	FDM	BINARY PHASE SHIFT KEYING (BPSK)	BPSK	FILTERED AMPLITUDE MODULATION	FILTERED AMPLITUDE MODULATION
BIT ERROR RATE	N/A	10 ⁻⁵ AT 24 DB	10 ⁻⁵ AT 38 DB	10 ⁻⁵ AT 38 DB	10 ⁻⁵ AT 38 DB
DUPLEX CIRCUITS PER 6-MHz CHANNEL	224	28	14	8,100	4,000
DUPLEX CIRCUITS/ CABLE SYSTEM	448	252	42	16,300	16,300
COST	\$1,850	\$950	\$1,000	\$3,950	\$4,600
OTHER FEATURES/ COMMENTS	-	-	-	-	-

IS/JM 520	IS/JM MODEL 620	IS/JM MODEL 630	IS/JM ⁽³⁾ MODEL 651	IS/JM ⁽³⁾ MODEL 652	IS/JM 720 SERIES	IS/JM 810
AUDIO	DIGITAL	DIGITAL	DIGITAL	DIGITAL	DIGITAL OR ANALOG (AC- CESS CONTROL)	DIGITAL
N/A	6.6 KBIT/S	96 KBIT/S	96 KBIT/S	96 KBIT/S	1.2 KBIT/S	6-100 KBIT/S
N/A	MOST STO TO 4.8 KBIT/S	MOST STO TO 16.2 KBIT/S	MOST STO TO 8.6 KBIT/S	MOST STO TO 9.8 KBIT/S	1.2 KBIT/S	6-100 KBIT/S
N/A	TDM	TDM	TDM	TDM	N/A	TDM
1/1	1/1	5/8	5/5	5/5	2/2	5/5
YES	N/A	N/A	N/A	N/A	N/A	N/A
YES	ASYN	ASYN	ASYN	ASYN	N/A	POLLED
1	6	6	6	1	1 TO 10	8 INBOUND 8 OUTBOUND
N/A	6	6	0	6	6	6
N/A	7.2 KBIT/S	72 KBIT/S	N/A	N/A	1.2 KBIT/S	N/A
BELL 3002	RS 232 C	RS 232 C	RS 232 C	RS 232 C	RS 232 C	TTL 8 BIT PARALLEL
STO TYPE 500 PHONE SET	N/A	N/A	N/A	N/A	20 MA CURRENT LOOP	N/A
TABLETOP	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT	TABLETOP RACK MOUNT	WALL MOUNT	TABLETOP
AM	FREQUENCY SHIFT KEYING (FSK)	FSK	FSK	FSK	MFSK	FSK
N/A	10 ⁻⁸	10 ⁻⁸	10 ⁻⁸	10 ⁻⁸	N/A	10 ⁻⁹
100	75	6	6	6	70	48 ⁽¹⁾
100	70	30	30	30	255	240
\$870	\$2,750	\$2,750	\$2,500	\$800	\$770 ⁽⁵⁾	\$1,316
-	-	-	-	-	-	-

MANUFACTURER/ PRODUCT	IS/3M 820	IS/3M S30	IS/3M 840	IS/3M MODEL 920	IS/3M ⁽⁵⁾ MODEL 925/926	IS/3M MODEL 930
TRANSMISSION SUPPORTED	DIGITAL	DIGITAL	DIGITAL	DIGITAL	DIGITAL	DIGITAL
NETWORK TRANSFER RATE	0-100 KBIT/S	0-100 KBIT/S	0-100 KBIT/S	0-10 KBIT/S	0-0.0 KBIT/S	TO 100 KBIT/S
PORT SPEEDS	150, 300, 600, 1.2K, 2.4K, 4.8K, 9.6K, & 10.2K BIT/S	150, 300, 600, 1.2K, 2.4K, 4.8K, & 9.6K BIT/S	0-100 KBIT/S	ASYNC. TO 10 KBIT/S SYNC. TO 0.0 KBIT/S	0-0.0 KBIT/S	0-10 KBIT/S
ACCESS METHODS	TDM AUTOPOLL	TDM AUTOPOLL	TDM AUTOPOLL	DIRECT	FDM	DIRECT
NO. OF 6 MHz CHANNELS USED (TRANSMIT/RECEIVE)	5/5	5/5	5/5	1/1	1/2	6/5
HALF-DUPLEX SUPPORT	N/A	N/A	N/A	ASYNC. SYNC	ASYNC	ASYNC
FULL DUPLEX SUPPORT	ASYNC	ASYNC	ASYNC	ASYNC. SYNC	ASYNC	ASYNC
NO. OF PORTS PER UNIT	1 TO 4	1	4	1	1	1
NO. OF CONTROL PORTS	0	0	0	0	0	0
AGGREGATE DATA RATE	100 KBIT/S	100 KBIT/S	100 KBIT/S	N/A	0.5 KBIT/S	N/A
INTERFACES	RS-232 C	RS-232 C	TYL 32 BIT PARALLEL	RS-232 C	RS-232 C	RS-232 C
OPTIONAL INTERFACES	N/A	N/A	N/A	20 MA ⁽¹⁾ CURRENT LOOP	N/A	N/A
MOUNTING	TABLETOP, RACK MOUNT	TABLETOP	TABLETOP, RACK MOUNT	TABLETOP, WALL MOUNT	TABLETOP	TABLETOP WALL MOUNT
MODULATION	FSK	FSK	FSK	RFSK	FSK	RFSK
BIT ERROR RATE	10 ⁻⁹	10 ⁻⁹	10 ⁻⁹	10 ⁻⁹ AT 30 DB	10 ⁻⁹	10 ⁻⁹ AT 30 DB
DUPLEX CIRCUITS PER 6-MHz CHANNEL	82 ⁽⁶⁾	48 ⁽⁷⁾	48 ⁽⁸⁾	70	70	7.5
DUPLEX CIRCUITS/ CABLE SYSTEM	240	240	240	70	220	30
COST	\$1,060 (WITH BUFFER \$2,000)	\$1,140	\$1,000	\$300	\$500	\$025
OTHER FEATURES/ COMMENTS	-	-	-	-	-	-

IS/3M MODEL 960	IS/3M ¹⁰ MODEL 965/964	IS/3M MODEL 5991	IS/3M 10M ATTACH	SYTER LN 20/100	SYTER LN 20/200	SYTER LN 40/100
DIGITAL	DIGITAL	DIGITAL	DIGITAL (32-PORT CATV DEVICE)	DIGITAL	DIGITAL	DIGITAL
TO 76.8 KBIT/S	56 KBIT/S	TO 2.1 MBIT/S	4.717 MBIT/S	120 KBIT/S	120 KBIT/S	2 MBIT/S
1.2, 2.4, 4.0, 9.6, 10, 2, 30, 4, & 76 KBIT/S	56 KBIT/S (40, 56, & 100 KBIT/S OPTIONAL)	100K TO 2.1M BIT/S	2,360 MBIT/S	75 TO 10.2K BIT/S	75 TO 10.2K BIT/S	1 MBIT/S
DIRECT	FDM	DIRECT	N/A	FDM/FM CSMA/CD	FDM/FM CSMA/CD	FDM/FM CSMA/CD
5/5	5/5	1/1	1/1	5/5	5/5	5/5
BSC, SYNC	N/A	N/A	PHOTOCD TRANSPARENT	ASYN	ASYN	ASYN
BSC, SYNC	SYNC	ASYN	N/A	ASYN, BSC	ASYN, BSC	ASYN, BSC
1	1	1	4 TO 32	2 ¹²	0 ¹²	1
0	0	0	0	0	0	0
N/A	56 KBIT/S	100K TO 2.1M BIT/S	N/A	10 KBIT/S	20 KBIT/S	1 MBIT/S
RS-232-C	CCITT V.36	TTL 8-PIN DIP	BNC CONNECTOR	RS-232-C	RS-232-C	PARALLEL DMA
N/A	0/A	N/A	N/A	N/A	N/A	UNIBUS INTEL MULTIBUS IBM BYTE MUX
TABLETOP, WALL MOUNT	TABLETOP	CARD CAGE	RACK MOUNT	TABLETOP	TABLETOP, RACK MOUNT	RACK MOUNT
MFSK	MFSK	FSK	BIPOLAR BIPHASE	FSK	FSK	FSK
10 ⁻⁹ AT 30 DB	10 ⁻⁹	10 ⁻⁸	10 ⁻⁹	10 ⁻¹²	10 ⁻¹²	10 ⁻¹²
7.5	VARIES-900 KHZ SPACING	1	N/A	2,900	2,900	1
30	37	1	N/A	12,000	12,000	5
8000	51,200	3040	55,750	51,175	54,200	55,500
FEATURES DATA TRANSPARENCY	-	-	-	USES DMA COMMAND LANGUAGE	USES DMA COMMAND LANGUAGE	N/A

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